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㊴ Multilens imaging apparatus with correction of misregistration.

㊼ This invention relates to a multi-lens imaging apparatus and, more particularly, to a multi-lens imaging apparatus for obtaining a single high-fine image by synthesizing a plurality of images obtained by picking up an image of a common object using a plurality of imaging systems and to an apparatus which can provide an image having an aspect ratio different from that of an image obtained by a single imaging apparatus, especially, a panoramic image, by synthesizing a plurality of images using a plurality of imaging systems. This invention has as its object to obtain a high-fine image by synthesizing images from a plurality of imaging systems and, more specifically, to correct mis-registration such as keystone distortions generated in the images.

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FIG. 5A
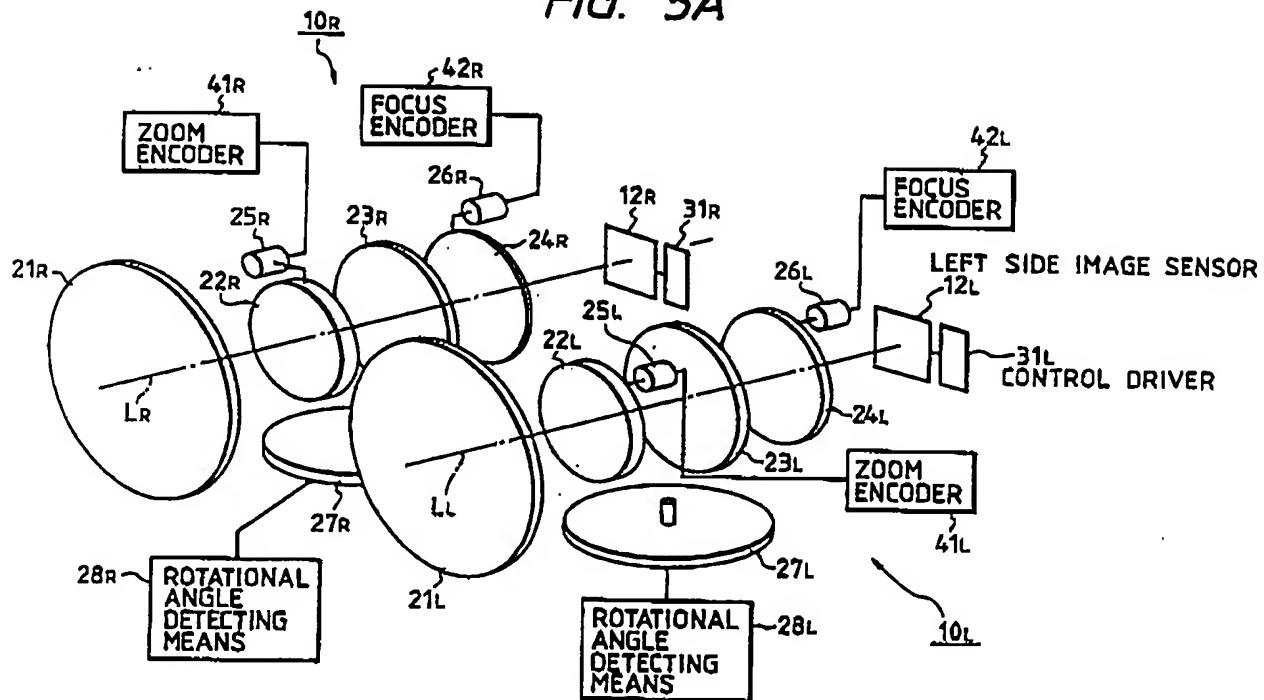
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BACKGROUND OF THE INVENTION

Field of the Invention

5   The present invention relates to a multi-lens imaging apparatus and, more particularly, to a multi-lens imaging apparatus which obtains a single high-fine image by synthesizing a plurality of images obtained by picking up a common object image using a plurality of imaging systems and to an apparatus which can provide a image having a different aspect ratio from that of a image obtained by a single imaging apparatus, for example, a panoramic image, by synthesizing a plurality of images obtained using a plurality
10   of imaging optical systems.

Related Background Art

        When an ultra high-fine image consisting of 4,000 x 4,000 pixels is picked up by an imaging system,
15   and the picked-up image is displayed on an ultra high-fine monitor, problems associated with techniques for achieving a high density and a high sensitivity in the imaging system are posed. As a method of solving such problems in the imaging system, the principle of a multi-lens imaging apparatus for picking up an image of a common object using two imaging systems each having a small number of pixels, and obtaining a single high-fine image by synthesizing the two images obtained by the two imaging systems has been
20   proposed. In the multi-lens imaging apparatus based on this principle, as shown in Fig. 1, right and left side imaging systems 110_R and 110_L are prepared, and pick up an image of an object 101 by shifting their sampling points by a 1/2 spatial phase pitch. A right side image I_R obtained by the right side imaging system 110_R and a left side image I_L obtained by the left side imaging system 110_L are synthesized by a microprocessor (to be referred to as a "CPU" hereinafter) 120, thereby obtaining a single high-fine output
25   image I_{OUT} as compared to a image obtained when the image of the object 101 is picked up by a single imaging system.
        Fig. 2 is an explanatory view for explaining a basic arrangement of the right and left side imaging systems 110_R and 110_L shown in Fig. 1.
        The left side imaging system 110_L is constituted by a left side imaging optical system 111_L and a left
30   side image sensor 112_L, and the right side imaging system 110_R is constituted by a right side imaging optical system 111_R and a right side image sensor 112_R. The right and left side imaging optical systems 111_R and 111_L have equivalent specifications, and each comprises a zoom lens. The right and left side image sensors 112_R and 112_L have equivalent specifications, and each comprises a camera tube such as a saticon or a solid-state imaging element such as a CCD. Optical axes L_R and L_L of the right and left imaging
35   systems 110_R and 110_L cross almost at a point O on an object surface 102, and these systems are arranged at positions axially symmetrical about a normal O-O' to the object surface 102. When the angle formed between each of the optical axes L_R and L_L and the normal O-O' to the object surface 102 (to be referred to as an "inclination angle" hereinafter) is represented by θ, 2θ is defined as the convergence angle.
40   In the multi-lens imaging apparatus, when the object distance is changed, the convergence angle 2θ is changed by rotating each of the right and left side imaging systems 110_R and 110_L about an X mark shown in Fig. 2 in accordance with the change in object distance, thus performing an imaging operation.
        However, in the above-mentioned multi-lens imaging apparatus, only the principle shown in Fig. 1 and the results of principle experiments for demonstrating the principle are presented, and no detailed
45   arrangement of the multi-lens imaging apparatus is presented. Thus, a problem associated with how to arrange the detailed multi-lens imaging apparatus utilizing the above-mentioned principle remains unsolved. Since the optical axes L_R and L_L of the right and left side imaging systems 110_R and 110_L are inclined with respect to the object surface 102, the right and left side images I_R and I_L obtained by the right and left side image sensors 112_R and 112_L suffer from trapezoidal distortions (to be referred to as "keystone distortions"
50   hereinafter), as shown in Fig. 3. As a result, when the right and left side images I_R and I_L are merely synthesized, a high-fine image cannot be obtained.
        Since the optical systems are arranged to have a convergence angle therebetween in principle, mis-registration between images obtained from the two imaging operation systems may occur. Fig. 4A shows the outline of mis-registration in a multi-lens imaging system. The system shown in Fig. 4A includes
55   imaging optical systems (lenses) 910 and 920, and image sensors 911 and 921. The imaging optical systems 910 and 920 have optical axes 912 and 922, respectively. When an object image is picked up while the optical axes 912 and 922 are inclined through θ in the x-z plane with respect to a central axis O-O', an arbitrary object point on an object surface is represented by P. At this time, if image points of the

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image sensors 911 and 921 with respect to P are respectively represented by R' and L', since R' ≠ L', mis-registration occurs, and two images with respect to the object point P are formed on a simply added synthesized image 930, as shown in Fig. 4B. As a result, a high-fine image cannot be provided.

Conventionally, as a panoramic imaging apparatus using a plurality of imaging optical systems and designed for dynamic images, for example, Japanese Laid-Open Patent Application No. 63-8641 is known. In an apparatus of this type, in general, the angle formed between the imaging optical systems is set by mechanical adjustment, so that image fields contact each other. However, it is very difficult to strictly register two adjacent images, and the boundary line between the two images normally becomes conspicuous. For the same reason as described above, since it is difficult to re-focus objects having different object distances or to perform zooming of these objects, the above-mentioned apparatus is limited to a cut photographing use in units of scenes.

As a method of changing the aspect ratio of a frame of a television or video signal (e.g., conversion between 4 : 3 of the NTSC and 16 : 9 of the HD or ED2), a method of trimming upper and lower portions or right and left portions of the frame is known. In this method, since a picked-up image is partially used, when an image is picked by an NTSC camera using a 4 : 3 image sensor, and is output onto a 16 : 9 HD monitor, a total of 25% upper and lower images are lost in addition to the fact that the number of pixels is originally short, thus considerably deteriorating image quality. Conversely, when an image is picked up by a 16 : 9 HD camera, and is output onto a 4 : 3 NTSC monitor, no problem associated with image quality is posed, but the horizontal field angle is decreased by 1/3.

SUMMARY OF THE INVENTION

It is an object of the present invention to obtain a high-fine image by synthesizing images from a plurality of imaging systems and, more specifically, to correct mis-registration such as keystone distortions generated in the images.

In order to achieve the above object, there is provided an apparatus comprising detection means for detecting a mis-registration amount between imaging systems, and means for controlling at least a mechanism system or an image process system, so that the mis-registration amount detected by the detection means becomes equal to or smaller than a predetermined value, whereby images obtained from the imaging systems are synthesized while being registered with each other.

In order to achieve the above object, there is also provided an apparatus comprising means for detecting imaging conditions of a plurality of imaging systems, means for detecting position information of an object from image signals output from the imaging systems, and means for synthesizing images output from the imaging systems on the basis of the imaging conditions and the position information.

According to the present invention, an image having a desired aspect ratio and almost free from image deterioration can be obtained, and a panoramic image in which a boundary line is not conspicuous can also be obtained.

According to the present invention, when a plurality of images are synthesized, the mis-registration amount of overlapping images may be partially detected.

According to the present invention, means for setting a convergence angle of imaging systems to be a predetermined value may be arranged so as to change the aspect ratio of an image.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view for explaining the principle of a multi-lens imaging apparatus for obtaining a single high-fine image by synthesizing two images obtained by picking up an image of a common object using two imaging systems;

Fig. 2 is an explanatory view for explaining a basic arrangement of right and left side imaging systems shown in Fig. 1;

Fig. 3 is an explanatory view for explaining keystone distortions generated in images obtained by right and left side image sensors shown in Fig. 1;

Figs. 4A and 4B are explanatory views of mis-registration occurring in the prior art;

Figs. 5A and 5B show a multi-lens imaging apparatus according to an embodiment of the present invention, in which Fig. 5A is a perspective view showing the arrangement of right and left imaging systems, and Fig. 5B is a block diagram for explaining operations of keystone distortion correction signal generation portions;

Fig. 6 is an explanatory view for explaining the principle of correcting keystone distortions in the keystone distortion correction signal generation portions shown in Fig. 5B;

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Fig. 7 is an explanatory view for explaining the principle of correcting keystone distortions in the keystone distortion correction signal generation portions shown in Fig. 5B;

Fig. 8 is an explanatory view for explaining the principle of correcting keystone distortions in the keystone distortion correction signal generation portions shown in Fig. 5B;

5 Fig. 9 is an explanatory view for explaining operations of camera tube electron beam scanning locus control drivers shown in Fig. 5B;

Fig. 10 is a perspective view showing the arrangement of right and left side imaging systems in a multi-lens imaging apparatus according to another embodiment of the present invention;

Fig. 11 is a block diagram for explaining operations of correction conversion portions in the multi-lens 10 imaging apparatus according to the embodiment shown in Fig. 10;

Fig. 12 is a perspective view showing the arrangement of right and left side imaging systems in a multi-lens imaging apparatus according to still another embodiment of the present invention;

Fig. 13 is a block diagram showing operations of correction optical systems shown in Fig. 12;

Fig. 14 is an explanatory view for explaining the principle of correcting keystone distortions in the 15 correction optical systems shown in Fig. 12;

Fig. 15 is an explanatory view for explaining the principle of correcting keystone distortions in the correction optical systems shown in Fig. 12;

Fig. 16 is an explanatory view for explaining the principle of correcting keystone distortions in the correction optical systems shown in Fig. 12;

20 Figs. 17A and 17B show a multi-lens imaging apparatus according to still another embodiment of the present invention, in which Fig. 17A is a perspective view showing the arrangement of right and left side imaging systems, and Fig. 17B is a block diagram for explaining a correction method of keystone distortions;

Fig. 18 is an explanatory view for explaining operations of a keystone distortion conversion portion and a 25 subtraction process circuit shown in Fig. 17B;

Fig. 19 is a graph showing the relationship between the image difference and the inclination angle (conversion variable);

Figs. 20A and 20B show a multi-lens imaging apparatus according to still another embodiment of the present invention, in which Fig. 20A is a perspective view showing the arrangement of right and left side 30 imaging systems, and Fig. 20B is a block diagram for explaining a correction method of keystone distortions;

Figs. 21A to 21C show a multi-lens imaging apparatus according to still another embodiment of the present invention, in which Fig. 21A is a perspective view showing the arrangement of right and left side imaging systems, Fig. 21B is a block diagram for explaining an operation of a control portion, and Fig. 35 21C is a block diagram for explaining an image synthesizing operation;

Fig. 22 is an explanatory view for explaining a basic arrangement of imaging systems in the multi-lens imaging apparatus according to the embodiment shown in Figs. 21A to 21C;

Fig. 23 is a view for explaining response characteristics of each convergence angle motor shown in Fig. 21A;

40 Figs. 24A and 24B show a multi-lens imaging apparatus according to still another embodiment of the present invention, in which Fig. 24A is a perspective view showing the arrangement of right and left side imaging systems, and Fig. 24B is a block diagram for explaining an operation of a calculation control portion;

Figs. 25A and 25B show a multi-lens imaging apparatus according to still another embodiment of the 45 present invention, in which Fig. 25A is a perspective view showing the arrangement of right and left side imaging systems, and Fig. 25B is a block diagram for explaining an operation of a calculation control portion;

Figs. 26A and 26B show a multi-lens imaging apparatus according to still another embodiment of the present invention, in which Fig. 26A is a perspective view showing the arrangement of right and left side 50 imaging systems, and Fig. 26B is a block diagram for explaining an operation of a calculation control portion;

Fig. 27 is a block diagram for explaining an operation of a correlation calculation process portion in a multi-lens imaging apparatus according to still another embodiment of the present invention;

Fig. 28 is a block diagram for explaining an operation of a magnification correlation calculation process 55 portion in a multi-lens imaging apparatus according to still another embodiment of the present invention;

Fig. 29 is an explanatory view for explaining a method of shortening the correlation calculation time in the magnification correlation calculation process portion shown in Fig. 28;

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Fig. 30 is an explanatory view for explaining another method of shortening the correlation calculation time in the magnification correlation calculation process portion shown in Fig. 28;

Fig. 31 is a view showing a basic arrangement according to still another embodiment of the present invention;

Fig. 32 is a perspective view of optical systems of the embodiment shown in Fig. 31;

Fig. 33 is a diagram showing the flow of a signal process for calculating a mis-registration amount;

Fig. 34 is a view for explaining a problem;

Fig. 35 is a diagram showing the flow of a compensation signal process in the embodiment shown in Fig. 31;

Fig. 36 is a diagram showing the flow of a image signal process in the embodiment shown in Fig. 31;

Fig. 37 is a perspective view showing optical systems according to still another embodiment of the present invention;

Fig. 38 is a diagram showing the flow of a compensation signal process in the embodiment shown in Fig. 37;

Fig. 39 is a perspective view showing optical systems according to still another embodiment of the present invention;

Fig. 40 is a diagram showing the flow of a compensation signal process in the embodiment shown in Fig. 39;

Fig. 41 is a perspective view showing optical systems according to still another embodiment of the present invention;

Fig. 42 is a diagram showing the flow of a compensation signal process in the embodiment shown in Fig. 41;

Fig. 43 is a perspective view showing optical systems according to still another embodiment of the present invention;

Fig. 44 is a diagram showing the flow of a signal process for calculating a mis-registration amount;

Fig. 45 is a perspective view for explaining an optical effect;

Fig. 46 is an explanatory view for explaining a method of obtaining an image having a desired aspect ratio;

Fig. 47 is an explanatory view of the aspect ratio;

Fig. 48 is a view showing an optical basic arrangement;

Fig. 49 is a view showing a basic arrangement according to still another embodiment of the present invention;

Fig. 50 is a perspective view showing the detailed arrangement of the embodiment shown in Fig. 49;

Fig. 51 is a block diagram showing relationships among functions in the embodiment shown in Fig. 49;

Fig. 52 is an explanatory view associated with a method of calculating three-dimensional position information of an object;

Fig. 53 is an explanatory view associated with a method of calculating two-dimensional position information of an object;

Figs. 54A and 54B are views showing a correlation calculation process;

Fig. 55 is a graph showing a correlation value; and

Fig. 56 is an explanatory view of an image correction process.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figs. 5A and 5B show an arrangement of a multi-lens imaging apparatus according to an embodiment of the present invention.

The multi-lens imaging apparatus of this embodiment obtains a single high-fine image by synthesizing two images obtained by picking up an image of a common object using two imaging systems (right and left side imaging systems 10_R and 10_L)

The arrangement of the right and left side imaging systems 10_R and 10_L will be described in detail below with reference to Fig. 5A.

The left side imaging system 10_L includes a left side imaging optical system 11_L (see Fig. 8), a left side image sensor 12_L comprising a camera tube, and a camera tube electron beam scanning locus control driver 31_L for controlling the locus of scanning of the electron beam emitted from the camera tube constituting the left side image sensor 12_L. The left side imaging optical system 11_L includes lens groups 21_L to 24_L including a zoom lens group 22_L and a focus lens group 24_L, a zoom motor 25_L as a driving system for driving the zoom lens group 22_L, a focus motor 26_L as a driving system for driving the focus lens group 24_L, a mechanism system (not shown) and a driving system (convergence angle motor 27_L) for

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integrally rotating the left side imaging optical system 11_L and the left side image sensor 12_L in a plane including an optical axis L_L, and a rotational angle detecting means 28_L for detecting the rotational angle of the convergence angle motor 27_L. As the rotational angle detecting means 28_L, for example, an externally attached member such as a rotary encoder may be used, or a means such as a pulse motor for detecting
5 the rotational angle by the driving system itself according to a driving method may be used. The right side imaging system 10_R has the same arrangement as that of the left side imaging system 10_L.

Assume that when the focus motor 26_L and the zoom motor 25_L of the left side imaging optical system 11_L are independently controlled by signals from a focus encoder 42_L and a zoom encoder 41_L, and a focus motor 26_R and a zoom motor 25_R of a right side imaging optical system 11_R are independently controlled
10 by signals from a focus encoder 42_R and a zoom encoder 41_R, a focal length f of the left side imaging optical system 11_L always coincides with a focal length f of the right side imaging optical system 11_R, and an image formation magnification β of the left side imaging optical system 11_L always coincides with an image formation magnification β of the right side imaging optical system 11_R.

At this time, a keystone distortion correction signal generation portion 32_L shown at the left side in Fig.
15 5B can calculate the focal length f of the left side imaging optical system 11_L on the basis of a signal from the zoom encoder 41_L, and a keystone distortion correction signal generation portion 32_R shown at the right side in Fig. 5B can calculate the focal length f of the right side imaging optical system 11_R on the basis of a signal from the zoom encoder 41_R. Also, since the keystone distortion correction signal generation portion 32_L can calculate an object distance to the left side imaging optical system 11_L on the basis of a signal from
20 the focus encoder 42_L, it can calculate the image formation magnification β of the left side imaging optical system 11_L. Similarly, the keystone distortion correction signal generation portion 32_R can calculate the image formation magnification β of the right side imaging optical system 11_R on the basis of a signal from the focus encoder 42_R. Furthermore, the keystone distortion correction signal generation portions 32_R and 32_L can calculate inclination angles θ on the basis of signals from the corresponding rotational angle
25 detecting means 28_R and 28_L.

As shown in Fig. 5B, the multi-lens imaging apparatus of this embodiment further includes the keystone distortion correction signal generation portion 32_L for generating a keystone distortion correction signal on the basis of the output signals from the rotational angle detecting means 28_L, the zoom encoder 41_L, and the focus encoder 42_L of the left side imaging optical system 11_L, and outputting the keystone distortion
30 correction signal to the camera tube electron beam scanning locus control driver 31_L, the keystone distortion correction signal generation portion 32_R for generating a keystone distortion correction signal on the basis of the output signals from the rotational angle detecting means 28_R, the zoom encoder 41_R, and the focus encoder 42_R of the right side imaging optical system 11_R, and outputting the keystone distortion correction signal to a camera tube electron beam scanning locus control driver 31_R, and a synthesizing
35 process portion 38 for forming a single high-fine image by synthesizing a right side image I_R sent from a right side image sensor 12_R and a left side image I_L sent from the left side image sensor 12_L. Note that the high-fine image formed by the synthesizing process portion 38 is output to a high fine monitor 40, and is displayed thereon.

The principle of correcting keystone distortions in the keystone distortion correction signal generation
40 portions 32_R and 32_L will be described below with reference to Figs. 6 to 8.

When keystone distortions are respectively generated in the left side image I_L obtained by the left side image sensor 12_L constituting the left side imaging system 10_L and in the right side image I_R obtained by the right side image sensor 12_R constituting the right side imaging system 10_R, if a point A on the Y-axis of a required image I indicated by a broken line in Fig. 6 is defined as a reference point, a point A_L on the left
45 side image I_L corresponding to the point A is deviated leftward in Fig. 6 by a horizontal deviation amount Δy, and a point A_R on the left side image I_R corresponding to the point A is deviated rightward in Fig. 6 by a horizontal deviation amount Δy.

If an arbitrary point P_0 on the required image I indicated by a broken line in Fig. 7 is defined as a reference point, a point P_1 on the left side image I_R corresponding to the point P_0 is deviated rightward in
50 Fig. 7 by a horizontal deviation amount $\Delta y_0'$ and is deviated upward in Fig. 7 by a vertical deviation amount $\Delta z_0'$ if the coordinates of the point P_0 are represented by (y_0', z_0'), and the coordinates of the point P_1 are represented by $(y_0' + \Delta y_0', z_0' + \Delta z_0')$. However, the horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ can be calculated from the focal length f and the image formation magnification β of the right side imaging optical system 11_R and the inclination angle θ of the right side imaging system 10_R. This principle
55 will be described in more detail below with reference to Fig. 8.

As shown in Fig. 8, when the right and left imaging systems 10_R and 10_L respectively perform imaging operations of an object surface 2, so that their optical axes L_R and L_L cross at a point O on the object surface 2, a conjugate object surface 3 passing through the point O on the object surface 2 and conjugate

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with the right side image sensor 12_R is assumed.

A point P_0 on the object surface 2 and a point P_1 on the conjugate object surface 3, which satisfy $OP_0 = OP_1$, will be examined below. In this case, an object height y_0 of the point P_0 with respect to the right side imaging optical system 11_R and an object height y_1 of the point P_1 with respect to the right side imaging optical system 11_R satisfy:

$$y_1 = y_0 \times \cos(\theta) \quad (1)$$

A length OQ_1 between an intersection Q_1 of a perpendicular drawn from the point P_1 to the optical axis L_R, and point 0 is expressed by:

$$OQ_1 = y_0 \times \sin(\theta) \quad (2)$$

Furthermore, if image heights on the right side image sensor 12_R with respect to the object heights y_0 and y_1 are respectively represented by y_0' and y_1', the horizontal deviation amount $\Delta y_0'$ is given by:

$$\Delta y_0' = y_1' - y_0' \quad (3)$$

If the distance (object distance) from the front-side principal point of the right side imaging optical system 11_R to the object surface 2 is represented by S_0, and the distance from the rear-side principal point of the right side imaging optical system 11_R to the image surface of the right side image sensor 12_R is represented by S_0' the image height y_1' is expressed by:

$$y_1' = y_1 \times S_0'/(S_0 - OQ_1) \quad (4)$$

Thus, from equations (1), (2), and (4), the image height y_1' can be expressed by:

$$y_1' = S_0' \times y_0 \times \cos(\theta)/(S_0 - y_0 \times \sin(\theta)) \quad (5)$$

Also, the image height y_0' is expressed by:

$$y_0' = y_0 \times S_0'/S_0 \quad (6)$$

For this reason, from equations (3), (5), and (6), the horizontal deviation amount $\Delta y_0'$ can be expressed by:

$$\Delta y_0' = \{S_0' \times \cos(\theta)/(S_0' - y_0' \times \sin(\theta)) - 1\} \times y_0' \quad (7)$$

Similarly, the vertical deviation amount $\Delta z_0'$ can be expressed by:

$$\Delta z_0' = z_1' - z_0'$$
$$= \{S_0'/(S_0' - y_0' \times \sin(\theta)) - 1\} \times z_0' \quad (8)$$

In this case, the distance S_0' from the rear-side principal point of the right side imaging optical system 11_R to the image surface of the right side image sensor 12_R is expressed as follows using the focal length f and the image formation magnification β of the right side imaging optical system 11_R:

$$S_0' = f \times (1 - \beta) \quad (9)$$

Therefore, the horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ can be respectively calculated from the focal length f and the image formation magnification β of the right side imaging optical system 11_R and the inclination angle θ of the right side imaging system 10_R. The same applies to the left side imaging system 10_L.

The operation of the multi-lens imaging apparatus of this embodiment will be described below.

When the object surface 2 is located at an infinity distance position, no keystone distortions are generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R

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and 12_L. For this reason, the synthesizing process portion 38 synthesizes the right and left side images I_R and I_L without executing the keystone distortion correction of the right and left side images I_R and I_L, and outputs the synthesized image to the high fine monitor 40.

On the other hand, when the object surface 2 is located at a finite distance position, the right and left side imaging systems 10_R and 10_L are inclined in opposite directions by the convergence angle motors 27_R and 27_L, so that the right and left side imaging systems 10_R and 10_L are directed toward the object surface 2. Thereafter, the inclination angles θ of the right and left side imaging systems 10_R and 10_L are controlled by the convergence angle motors 27_R and 27_L, so that the sampling points on the optical axis L_L of the left side imaging system 10_L are shifted by a 1/2 spatial phase pitch from those on the optical axis L_R of the right side imaging system 10_R. At this time, in synchronism with control of the inclination angles θ by the convergence angle motors 27_R and 27_L, the magnification setting operations and focusing operations of the right and left side imaging optical systems 11_R and 11_L are performed using the zoom motors 25_R and 25_L and the focus motors 26_R and 26_L.

In this case, since the imaging operations are performed in a state wherein the right and left imaging systems 10_R and 10_L are inclined through the inclination angle θ, keystone distortions are generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R and 12_L. Therefore, in order to correct these keystone distortions, the keystone distortion correction signal generation portion 32_L of the left side imaging optical system 11_L calculates the horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ of each point on the left side image I_L obtained by the left side image sensor 12_L using the output signals from the rotational angle detecting means 28_L and the focus encoder 42_L and the zoom encoder 41_L from equations (7) to (9) described above, generates a keystone distortion correction signal for correcting the keystone distortion generated in the left side image I_L, and outputs the signal to the camera tube electron beam scanning locus control driver 31_L of the left side imaging optical system 11_L. In this case, the distance S_0' is calculated from equation (9). Alternatively, the distance S_0' may be calculated from the output signal from the focus encoder 42_L. The keystone distortion correction signal generation portion 32_R of the right side imaging optical system 11_R operates in the same manner as described above.

The camera tube electron beam scanning locus control driver 31_L of the left side imaging optical system 11_L changes the scanning locus of the electron beam emitted from the camera tube constituting the left side image sensor 12_L on the basis of the keystone distortion correction signal sent from the keystone distortion correction signal generation portion 32_L, thereby correcting the keystone distortion generated in the left side image I_L. More specifically, the camera tube electron beam scanning locus control driver 31_L of the left side imaging optical system 11_L changes the scanning locus of the electron beam by controlling a deflection circuit of the camera tube constituting the left side image sensor 12_L on the basis of the keystone distortion correction signal sent from the keystone distortion correction signal generation portion 32_L, thereby scanning the left side image I_L along a point $A_1 \rightarrow$ a point B_1, a point $A_2 \rightarrow$ a point B_2, a point $A_3 \rightarrow$ a point B_3, and a point $A_4 \rightarrow$ a point B_4, as indicated by the left-hand side figure in Fig. 9. As a result, the left side image I_L output from the camera tube constituting the left side image sensor 12_L is converted into the required image I, which is scanned along a point $a_1 \rightarrow$ a point b_1, a point $a_2 \rightarrow$ a point b_2, a point $a_3 \rightarrow$ a point b_3, and a point $a_4 \rightarrow$ a point b_4, as indicated by the right-hand side figure in Fig. 9, and the converted image is input to the synthesizing process portion 38.

In place of the rotational angle detecting means 28_R and 28_L, means for detecting relative postures of the right and left imaging systems 10_R and 10_L to obtain the inclination angles θ may be used. The right and left imaging optical systems 11_R and 11_L may be constituted using zoom lenses or fixed focal point lenses.

Fig. 10 is a perspective view showing the arrangement of the right and left side imaging systems 10_R and 10_L in a multi-lens imaging apparatus according to another embodiment of the present invention, and Fig. 11 is a block diagram for explaining operations of correction conversion portions 52_R and 52_L.

The multi-lens imaging apparatus of this embodiment has the following differences from the multi-lens imaging apparatus of the embodiment shown in Figs. 5A and 5B.

(1) Both the right and left side image sensors 12_R and 12_L comprise solid-state imaging device in place of the camera tubes.

(2) The apparatus of this embodiment does not have the camera tube electron scanning locus control drivers 31_R and 31_L of the right and left imaging systems 10_R and 10_L shown in Fig. 5A.

(3) The apparatus of this embodiment has a left side image memory 51_L for left side image data output from the left side image sensor 12_L, and a right side image memory 51_R for right side image data output from the right side image sensor 12_R, as shown in Fig. 11.

(4) The apparatus of this embodiment has a correction conversion portion 52_L (to be described later) between the left side image memory 51_L and the synthesizing processing portion 38, and also has a

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correction conversion portion 52_R (to be described later) between the right side image memory 51_R and the synthesizing processing portion 38.

The operation of the multi-lens imaging apparatus of this embodiment will be described below.

5　When the object surface 2 is located at an infinity distance position, since no keystone distortions are generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R and 12_L, right and left side image data respectively stored in the right and left image memories 51_R and 51_L are directly supplied to the synthesizing process portion 38 without executing keystone distortion correction of the right and left side images I_R and I_L, and the right and left side images I_R and I_L are synthesized by the synthesizing process portion 38. The synthesized image is then output to the high fine monitor 40.

10　On the other hand, when the object surface 2 is located at a finite distance position, the right and left side imaging systems 10_R and 10_L are inclined by the convergence angle motors 27_R and 27_L in opposite directions, so that the right and left side imaging systems 10_R and 10_L are directed toward the object surface 2. Thereafter, the inclination angles θ of the right and left side imaging systems 10_R and 10_L are controlled by the convergence angle motors 27_R and 27_L, so that the sampling points on the optical axis L_L

15　of the left side imaging system 10_L are shifted by a 1/2 spatial phase pitch from those on the optical axis L_R of the right side imaging system 10_R. At this time, in synchronism with control of the inclination angles θ by the convergence angle motors 27_R and 27_L, the magnification setting operations and focusing operations of the right and left side imaging optical systems 11_R and 11_L are performed using the zoom motors 25_R and 25_L and the focus motors 26_R and 26_L.

20　In this case, since the imaging operations are performed in a state wherein the right and left imaging systems 10_R and 10_L are inclined through the inclination angle θ, keystone distortions are generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R and 12_L. Therefore, in order to correct these keystone distortions, as shown in Fig. 11, the keystone distortion correction signal generation portion 32_L of the left side imaging optical system 11_L calculates the horizontal

25　and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ of each point on the left side image I_L obtained by the left side image sensor 12_L using the output signals from the rotational angle detecting means 28_L and the focus encoder 42_L and the zoom encoder 41_L from equations (7) to (9) described above, generates a keystone distortion correction signal for correcting the keystone distortion generated in the left side image I_L, and outputs the signal to the correction conversion portion 52_L. The correction conversion portion 52_L converts

30　the coordinate of the left side image data of the left side image I_L read out from the left side image memory 51_L so as to cancel the horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ on the basis of the keystone distortion correction signal sent from the keystone distortion correction signal generation portion 32_L, thereby correcting the keystone distortion generated in the left side image I_L. In this case, the distance S_0' is calculated from equation (9). Alternatively, the distance S_0' may be calculated from the output signal from

35　the focus encoder 42_L. The keystone distortion correction signal generation portion 32_R and the correction conversion portion 52_R of the right side imaging optical system 11_R perform the same operation as described above.

As a result, the synthesizing process portion 38 synthesizes the right and left side image data of the right and left side images I_R and I_L, which are respectively sent from the correction conversion portions 52_R

40　and 52_L, and in which the keystone distortions are corrected, so that a single high-fine synthesized image can be displayed on the high fine monitor 40.

In the multi-lens imaging apparatus of this embodiment, the output signal from the correction conversion portion 52_L is supplied to the synthesizing process portion 38. Alternatively, the output signal from the correction conversion portion 52_L may be stored again in the left side image memory 51_L, and thereafter,

45　the data may be supplied from the left side image memory 51_L to the synthesizing process portion 38. The same applies to the output signal from the other correction conversion portion 52_R.

Fig. 12 is a perspective view showing an arrangement of the right and left imaging systems 10_R and 10_L in a multi-lens imaging apparatus according to still another embodiment of the present invention, and Fig. 13 is a block diagram for explaining operations of correction optical systems 61_R and 61_L.

50　In the multi-lens imaging apparatus of this embodiment, lenses constituting correction optical systems 61_R and 61_L (to be described later) are decentered in the vertical direction with respect to the optical axes L_R and L_L so as to generate distortions, thereby correcting keystone distortions generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R and 12_L. More specifically, the arrangement of the multi-lens imaging apparatus is substantially the same as that of the multi-lens

55　imaging apparatus of the embodiment shown in Figs. 10 and 11, except that the apparatus of this embodiment has the correction optical system 61_L arranged between the left side imaging optical system 11_L and the left side image sensor 12_L, and the correction optical system 61_R arranged between the right side imaging optical system 11_R and the right side image sensor 12_R, in place of the correction conversion

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portions 52_L and 52_R.

The operation of the multi-lens imaging apparatus of this embodiment will be described below.

When the object surface 2 is located at an infinity distance position, since no keystone distortions are generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R and 12_L, the right and left side images I_R and I_L are synthesized by the synthesizing process portion 38 without executing keystone distortion correction of the right and left side images I_R and I_L, and the synthesized image is output to the high fine monitor 40.

On the other hand, when the object surface 2 is located at a finite distance position, the right and left side imaging systems 10_R and 10_L are inclined by the convergence angle motors 27_R and 27_L in opposite directions, so that the right and left side imaging systems 10_R and 10_L are directed toward the object surface 2. Thereafter, the inclination angles θ of the right and left side imaging systems 10_R and 10_L are controlled by the convergence angle motors 27_R and 27_L, so that the sampling points on the optical axis L_L of the left side imaging system 10_L are shifted by a 1/2 spatial phase pitch from those on the optical axis L_R of the right side imaging system 10_R. At this time, in synchronism with control of the inclination angles θ by the convergence angle motors 27_R and 27_L, the magnification setting operations and focusing operations of the right and left side imaging optical systems 11_R and 11_L are performed using the zoom motors 25_R and 25_L and the focus motors 26_R and 26_L.

In this case, since the imaging operations are performed in a state wherein the right and left imaging systems 10_R and 10_L are inclined through the inclination angle θ, keystone distortions are generated in the right and left side images I_R and I_L obtained by the right and left side image sensors 12_R and 12_L. Therefore, in order to correct these keystone distortions, as shown in Fig. 13, the keystone distortion correction signal generation portion 32_L of the left side imaging optical system 11_L calculates the horizontal and vertical deviation amounts $\Delta y_{0'}$ and $\Delta z_{0'}$ of each point on the left side image I_L obtained by the left side image sensor 12_L using the output signals from the rotational angle detecting means 28_L and the focus encoder 42, and the zoom encoder 41_L from equations (7) to (9) described above, generates a keystone distortion correction signal for correcting the keystone distortion generated in the left side image I_L, and outputs the signal to the correction optical system 61_L of the left side imaging optical system 11_L. The correction optical system 61_L of the left side imaging optical system 11_L decenters at least one of lenses constituting the correction optical system 61_L in the vertical direction with respect to the optical axis L_L on the basis of the keystone distortion correction signal sent from the keystone distortion correction signal generation portion 32_L so as to generate a distortion, thereby correcting the keystone distortion generated in the left side image I_L. In this case, the distance S_0' is calculated from equation (9). Alternatively, the distance S_0' may be calculated from the output signal from the focus encoder 42_L. The keystone distortion correction signal generation portion 32_R and the correction optical system 61_R of the right side imaging optical system 11_R perform the same operations as described above.

The principle of correcting keystone distortions will be described below with reference to Fig. 14.

The object surface 2 is inclined through the inclination angle θ with respect to the optical axis L_R, and its image is formed on the right side image sensor 12_R. If the distance from the object surface 2 to the right side imaging optical system 11_R is represented by S_1, the distance from the right side imaging optical system 11_R to the image surface of the right side image sensor 12_R is represented by S_1', and a point O on the object surface 2 is defined as an intersection between the optical axis L_R and the object surface 2, an image formation magnification β_H at a height H of the object surface 2 is expressed as follows by a paraxial calculation:

$$\beta_H = S_1'/(S_1 + H \times \sin(\theta))$$
$$= \beta \times \{S_1/(S_1 + H \times \sin(\theta))\} \qquad (10)$$

where

$\beta =$ the image formation magnification at the point O on the object surface 2

A decentering distortion d generated when a concave lens 62_R of the correction optical system 61_R - (consisting of the concave lens 62_R and a convex lens 63_R) arranged between the right side imaging optical system 11_R and the right side image sensor 12_R is parallelly decentered by a distance E in the vertical direction in Fig. 15 is given, in consideration of up to a third-order term, by:

$$d = -(E/2) \times (\tan(\omega))^2 \times (3 \times V_{E1} - V_{E2}) \qquad (11)$$

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for $\tan(\omega) = H/f$ (f = the focal length of the right side imaging optical system 11R)

Note that V_{E1} and V_{E2} included in equation (11) are parallel decentering distortion coefficients of the correction optical system 61_R, and are respectively given by:

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$$V_{E1} = (h \times \phi \times V_q - a \times V_p) - (h \times \phi \times B_q - a \times B_p) \qquad (12)$$

$$V_{E2} = h \times \phi \times P_q - a \times P_p \qquad (13)$$

10　where

ϕ = the refracting power of the correction optical system 61_R
V_p = the third-order distortion of the convex lens 63_R
B_p = the astigmatism coefficient of the convex lens 63_R
P_p = the Petzval's sum of the convex lens 63_R
15　V_q = the third-order distortion on the object surface 2 side of the concave lens 62_R
B_q = the astigmatism coefficient on the object surface 2 side of the concave lens 62_R
P_q = the Petzval's sum on the object surface 2 side of the concave lens 62_R
h = the incident position of the paraxial object ray onto the correction optical system 61_R
a = the incident angle of the paraxial object ray onto the correction optical system 61_R

20　Since the distortion generated when the correction optical system 61_R is decentered is calculated in the above-mentioned procedures, keystone distortion correction shown in Fig. 16 can be attained by decentering the correction optical system 61_R so that the signs of $\beta_H/\beta - 1$ and the decentering distortion d are opposite to each other:

25　$$d = \beta_H/\beta - 1 \qquad (14)$$

In this manner, a keystone distortion can be corrected in a region up to the third order. Note that the parallel decentering amount E of the correction optical system 61_R can be calculated from equations (10) to (14).

When the right side image I_R in which the keystone distortion is corrected in this manner, and which is 30　obtained from the right side image sensor 12_R, and the left side image I_L in which the keystone distortion is similarly corrected, and which is obtained from the left side image sensor 12_L are synthesized by the synthesizing process portion 38, a single high-fine image can be displayed on the high fine monitor 40 (see Fig. 13).

Figs. 17A and 17B show a multi-lens imaging apparatus according to still another embodiment of the 35　present invention.

The multi-lens imaging apparatus of this embodiment obtains a single high-fine image by synthesizing two images obtained by picking up an image of a common object using two imaging systems (right and left side imaging systems 10_R and 10_L).

The arrangement of the right and left side imaging systems 10_R and 10_L will be described in detail 40　below with reference to Fig. 17A.

The left side imaging system 10_L includes lens groups 21_L to 24_L including a zoom lens group 22_L and a focus lens group 24_L, a zoom motor 25_L as a driving system for driving the zoom lens group 22_L, a focus motor 26_L as a driving system for driving the focus lens group 24_L, a mechanism system (not shown) and a driving system (convergence angle motor 27_L) for integrally rotating the left side imaging optical system 11_L 45　and a left side image sensor 12_L in a plane including an optical axis L_L, and a rotational angle detecting means 28_L for detecting the rotational angle of the convergence angle motor 27_L, which constitute a left side imaging optical system 11_L. As the rotational angle detecting means 28_L, for example, an externally attached member such as a rotary encoder may be used, or a means such as a pulse motor for detecting the rotational angle by the driving system itself according to a driving method may be used. The right side 50　imaging system 10_R has the same arrangement as that of the left side imaging system 10_L.

Assume that when the focus motor 26_L and the zoom motor 25_L of the left side imaging optical system 11_L are independently controlled by signals from the focus encoder 42_L and the zoom encoder 41_L, and a focus motor 26_R and a zoom motor 25_R of a right side imaging optical system 11_R are independently controlled by signals from a focus encoder 42_R and a zoom encoder 41_R, a focal length f of the left side 55　imaging optical system 11_L always coincides with a focal length f of the right side imaging optical system 11_R, and an image formation magnification β of the left side imaging optical system 11_L always coincides with an image formation magnification β of the right side imaging optical system 11_R.

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At this time, a calculation control portion 71 shown in Fig. 17B can calculate the focal length f of the left side imaging optical system 11_L on the basis of a signal from the zoom encoder 41_L, and can calculate the focal length f of the right side imaging optical system 11_R on the basis of a signal from the zoom encoder 41_R. Also, since the calculation control portion 71 can calculate an object distance to the left side imaging optical system 11_L on the basis of a signal from the focus encoder 42_L, it can calculate the image formation magnification β of the left side imaging optical system 11_L, and similarly, it can calculate the image formation magnification β of the right side imaging optical system 11_R on the basis of a signal from the focus encoder 42_R. Furthermore, the calculation control portion 71 can calculate inclination angles θ from the signals output from the rotational angle detecting means 28_R and 28_L.

The output signals from the zoom encoders 41_R and 41_L and the focus encoders 42_R and 42_L are input to the calculation control portion 71, as shown in Fig. 17B. The calculation control portion 71 can calculate the distance S_0' from the rear-side principal point of the left side imaging optical system 11_L to the image surface of the left side image sensor 12_L and the distance S_0' from the rear-side principal point of the right side imaging optical system 11_R to the image surface of the right side image sensor 12_R from equation (9) described above:

$$S_0' = f \times (1 - \beta) \qquad (9)$$

Left side image data of a left side image I_L output from the left side image sensor 12_L is stored in a left side image memory 72_L, and right side image data of a right side image I_R output from the right side image sensor 12_R is stored in a right side image memory 72_R.

The principle of correcting keystone distortions generated in the right and left images I_R and I_L by a keystone distortion conversion portion 73, second right and left side image memories 74_R and 74_L, and a subtraction process circuit 75 shown in Fig. 17B will be described below with reference to Figs. 18 and 19.

The keystone distortion conversion portion 73 calculates horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ of predetermined several image points from equations (7) and (8) described above using the left side image data read out from the left side image memory 72_L, the right side image data read out from the right side image memory 72_R, and the distances S_0' sent from the calculation control portion 71. At this time, the inclination angle θ is defined as a conversion variable (an angle is not detected), and the horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ are calculated by substituting, e.g., $\theta = \theta_1$ (θ_1 is an arbitrary value). Thereafter, the keystone distortion conversion portion 73 shifts the coordinates of the image points in the right and left side image memories 72_R and 72_L by the calculated horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$, and writes the shifted right and left side image data in the second right and left side image memories 74_R and 74_L, respectively. Thereafter, the subtraction process circuit 75 reads out the coordinate-shifted right and left side image data respectively from the second right and left side image memories 74_R and 74_L, and calculates a sum (to be referred to as an "image difference" hereinafter) δ_{s1} of the absolute values of differences of these data. Subsequently, the keystone distortion conversion portion 73 changes the inclination angle θ (conversion variable) to be $\theta = \theta_2$, and an image difference δ_{s2} is similarly calculated.

When the above-mentioned operations are repeated, since the relationship between the inclination angle θ (conversion variable) and the image difference δ_s can be obtained, as shown in, e.g., Fig. 19, an inclination angle θ_0 (conversion variable) at which the image difference δ_s assumes a minimum value is obtained. The keystone distortion conversion portion 73 calculates the horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$ of all image points of the left side image data from equations (7) and (8) using the inclination angle θ_0 (conversion variable) at which the image difference δ_s assumes a minimum value, thereafter, shifts the coordinates of all the image points of the left side image data by the calculated horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$, and writes the shifted left side image data in the second left side image memory 74_L. As a result, the left side image data in which the keystone distortion is corrected is written in the second left side image memory 74_L.

Therefore, when the left side image data in which the keystone distortion is corrected, and which is written in the second left side image memory 74_L, and the right side image data in which the keystone distortion is corrected, and which is written in the second right side image memory 74_R are synthesized by a synthesizing process portion (not shown), a single high-fine image can be displayed on a high fine monitor (not shown).

Figs. 20A and 20B show a multi-lens imaging apparatus according to still another embodiment of the present invention.

The arrangement of the multi-lens imaging apparatus of this embodiment is substantially the same as that of the multi-lens imaging apparatus of the embodiment shown in Figs. 17A and 17B, except that the

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right and left image sensors 12_R and 12_L comprise camera tubes, and the keystone distortion conversion portion 73 controls camera tube electron beam scanning locus drivers 31_R and 31_L according to the calculated horizontal and vertical deviation amounts $\Delta y_0'$ and $\Delta z_0'$.

Since the operations of the camera tube electron beam scanning locus drivers 31_R and 31_L and the principle of correcting keystone distortions in the multi-lens imaging apparatus of this embodiment are the same as those in the multi-lens imaging apparatuses in the embodiments shown in Figs. 5A and 5B and Figs. 17A and 17B, a repetitive description will be avoided here.

Figs. 21A to 21C show a multi-lens imaging apparatus according to still another embodiment of the present invention, and Fig. 22 shows a basic arrangement of imaging systems in the multi-lens imaging apparatus of the embodiment shown in Figs. 21A to 21C.

The multi-lens imaging apparatus of this embodiment obtains a single high-fine image by synthesizing two images obtained by picking up an image of a common object using two sets of imaging systems (right and left side imaging systems 10_R and 10_L).

As shown in Fig. 22, the left side imaging system 10_L is constituted by a left side imaging optical system 11_L and a left side image sensor 12_L, and the right side imaging system 10_R is constituted by a right side imaging optical system 11_R and a right side image sensor 12_R. The right and left side imaging optical systems 11_R and 11_L have equivalent specifications, and each comprises a zoom lens. The right and left side image sensors 12_R and 12_L have equivalent specifications, and each comprises a camera tube such as a saticon or a solid-state imaging element such as a CCD. Optical axes L_R and L_L of the right and left imaging systems 10_R and 10_L cross almost at a point O on an object surface 2, and these systems are arranged at positions axially symmetrical about a normal O-O' to the object surface 2.

In this multi-lens imaging apparatus, when the object distance is changed, the convergence angle 2θ is changed by rotating each of the right and left side imaging systems 10_R and 10_L about an X mark shown in Fig. 22 in accordance with the change in object distance, thus performing an imaging operation.

The arrangement of the right and left imaging systems 10_R and 10_L will be described in detail below with reference to Fig. 21A.

The left side imaging system 10_L includes lens groups 21_L to 24_L including a zoom lens group 22_L and a focus lens group 24_L, a zoom motor 25_L as a driving system for driving the zoom lens group 22_L, a focus motor 26_L as a driving system for driving the focus lens group 24_L, a mechanism system (not shown) and a driving system (convergence angle motor 27_L) for integrally rotating the left side imaging optical system 11_L and a left side image sensor 12_L in a plane including an optical axis L_L, and a rotational angle detecting means 28_L for detecting the rotational angle of the convergence angle motor 27_L, which constitute a left side imaging optical system 11_L. As the rotational angle detecting means 28_L, for example, an externally attached member such as a rotary encoder may be used, or a means such as a pulse motor for detecting the rotational angle by the driving system itself according to a driving method may be used. The right side imaging system 10_R has the same arrangement as that of the left side imaging system 10_L.

A control method for the convergence angle motors 27_R and 27_L will be described below with reference to Fig. 21B.

When the right and left imaging systems 10_R and 10_L perform imaging operations respectively at convergence angles $2\theta + \Delta\theta_R$ and $2\theta + \Delta\theta_L$ to have angular deviations $\Delta\theta_R$ and $\Delta\theta_L$ with respect to the predetermined convergence angle 2θ (see Fig. 22), the rotational angle detecting means 28_L detects the angular deviation $\Delta\theta_L$ with respect to an angle θ (see Fig. 22) formed between the optical axis L_L of the left side imaging system 10_L and the normal O-O' to the object surface 2, and the rotational angle detecting means 28_R detects the angular deviation $\Delta\theta_R$ with respect to an angle θ formed between the optical axis R_R of the right side imaging system 10_R and the normal O-O' to the object surface 2. The angular deviations $\Delta\theta_R$ and $\Delta\theta_L$ output from the rotational angle detecting means 28_R and 28_L are supplied to a control portion 231.

Assume that the convergence angle motors 27_R and 27_L have the following response characteristics.

For the sake of simplicity, as shown in Fig. 23, only a mis-registration amount Δa of a image output from the right side imaging system 10_R when the optical axis L_R of the right side imaging system 10_R is deviated by the angular deviation $\Delta\theta_R$ will be examined below. If the distance (object distance) from the front-side principal point of the right side imaging optical system 11_R to the object surface 2 is represented by S_0, the distance from the rear-side principal point of the right side imaging optical system 11_R to the right side image sensor 12_R is represented by S_1, and the deviation amount of the optical axis L_R of the right side imaging system 10_R in the object surface 2 is represented by Δy, when the angular deviation $\Delta\theta_R$ is small, we have:

$$S_0 \times \tan(\Delta\theta_R) = \Delta y \times \cos(\theta) \qquad (15)$$

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If the image formation magnification of the right side imaging optical system 11_R is represented by β, we have:

5　$\beta = \Delta a / \Delta y$　　(16)

Furthermore, if the focal length of the right side imaging optical system 11_R is represented by f, we have:

$S_0 = f \times (\beta - 1)/\beta$　　(17)

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From equations (15) to (17), the mis-registration amount Δa of the image is given by:

$\Delta a = \{f \times (\beta - 1) \times \tan(\Delta\theta_R)\}/\cos(\theta)$　　(18)

15　Therefore, assume that the convergence angle motor 27_R shown in Fig. 21A has sufficient response characteristics for an angle ($\Delta\theta_R$) necessary for correcting the mis-registration amount Δa of the image given by equation (18) to be equal to or smaller than an allowable value Δa_0. The same applies to the convergence angle motor 27_L of the left side imaging optical system 11_L

The control portion 231 supplies a correction signal $-\Delta\theta_L$ to the convergence angle motor 27_L of the left
20　side imaging system 10_L as a control target value, and supplies a correction signal $-\Delta\theta_R$ to the convergence angle motor 27_R of the right side imaging system 10_R as a control target value, as shown in Fig. 21B. As a result, the mis-registration amount Δa of the image obtained by each of the right and left imaging systems 10_R and 10_L can be corrected to be equal to or smaller than the allowable value Δa_0.

When the mis-registration amounts of the images are corrected as described above, a image signal
25　output from the left side image sensor 12_L is stored in a left side image memory 232_L, and a image signal output from the right side image sensor 12_R is stored in a right side image memory 232_R, as shown in Fig. 21C. Thereafter, these images are synthesized by a synthesizing process circuit 233, and a synthesized image signal is output.

Therefore, since the multi-lens imaging apparatus of this embodiment can synthesize images obtained
30　by the right and left imaging systems 10_R and 10_L while registering the two images, if, for example, the convergence angle is controlled in advance so that the relative spatial phase between the right and left side image sensors 12_R and 12_L is shifted by a 1/2 pitch when the sampling points of the right and left image side sensors 12_R and 12_L are imaginarily projected onto an object, the synthesizing process circuit 233 can obtain a single high fine image.

35　In the multi-lens imaging apparatus of this embodiment, when a solid state imaging element is used as each of the right and left side image sensors 12_R and 12_L, either a single-sensor type element or two- or three-sensor type element via a color separation system may be used. When a camera tube is used as each of the right and left side image sensors 12_R and 12_L, either a single-tube type element or two- or three-tube type element via a color separation system may be used. The control portion 231 may supply a
40　correction signal $-(\Delta\theta_L + \Delta\theta_R)$ to one of the two convergence angle motors 27_R and 27_L as a control target value in place of respectively supplying the correction signals $-\Delta\theta_R$ and $-\Delta\theta_L$ to the two convergence angle motors 27_R and 27_L ascontrol target values.

Figs. 24A and 24B show a multi-lens imaging apparatus according to still another embodiment of the present invention.

45　In the multi-lens imaging apparatus of the embodiment shown in Figs. 21A to 21C, as can be understood from equation (18), when the focal lengths f of the right and left side imaging optical systems 11_R and 11_L are large, or when the allowable values Δa_0 of the mis-registration amounts of images are small, the correction signals $-\Delta\theta_R$ and $-\Delta\theta_L$ output from the control portion 231 also take small values (e.g., on the order of several seconds), and it becomes difficult to obtain angular response performance
50　necessary for correction under the influence of, e.g., non-sensitive bands of the convergence angle motors 27_R and 27_L.

In the multi-lens imaging apparatus of the embodiment shown in Figs. 24A and 24B, the image mis-registration amount Δa given by equation (18) is calculated, and is corrected by means other than the convergence angle motors 27_R and 27_L, thereby solving the above-mentioned problem. The apparatus of
55　this embodiment has the following differences from the multi-lens imaging apparatus of the embodiment shown in Figs. 21A to 21C.

(1) Zoom encoders 41_R and 41_L for detecting the focal lengths f of the right and left side imaging optical systems 11_R and 11_L are respectively provided to the zoom motors 25_R and 25_L.

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(2) Focus encoders 42_R and 42_L for detecting the object distances S_0 with respect to the right and left side imaging optical systems 11_R and 11_L are respectively provided to the focus motors 26_R and 26_L.

(3) The apparatus of this embodiment includes horizontal direction drive systems 243_R and 243_L for respectively driving the right and left side image sensors 12_R and 12_L in the horizontal direction.

(4) The apparatus of this embodiment also includes a calculation control portion 244 (to be described later; see Fig. 24B).

The operation of the multi-lens imaging apparatus of this embodiment will be described below.

In the left side imaging optical system 11_L, when the zoom motor 25_L is controlled by a signal from the zoom encoder 41_L, and the focus motor 26_L is controlled by an output signal from the focus encoder 42_L, the focal length f and the image formation magnification β are caused to always coincide with each other. In the right side imaging optical system 11_R, the focal length f and the image formation magnification β are similarly caused to always coincide with each other.

Therefore, the focal lengths f and the image formation magnifications β of the right and left side imaging optical systems 11_R and 11_L can be obtained from the output signals from the zoom encoders 41_R and 41_L, and the object distances S_0 with respect to the right and left side imaging optical systems 11_R and 11_L can be obtained from the output signals from the focus encoders 42_R and 42_L. For this reason, the output signals from the zoom encoders 41_R and 41_L and the focus encoders 42_R and 42_L are input to the calculation control portion 244, and the calculation control portion 244 calculates equation (18) described above, thus obtaining the mis-registration amounts Δa_0 of images. The calculation control portion 244 controls the horizontal direction drive systems 243_R and 243_L to move the right and left side image sensors 12_R and 12_L in the horizontal direction according to the calculated mis-registration amounts Δa_0 of the images, thereby correcting the mis-registration amounts Δa of the images to be equal to or smaller than the allowable value Δa_0.

As each of the zoom encoders 41_R and 41_L and the focus encoders 42_R and 42_L, for example, an externally attached member such as a potentiometer may be used, or a means such as a pulse motor for detecting the rotational angle by the driving system itself according to a driving method may be used. Also, each of the horizontal direction drive systems 243_R and 243_L may comprise, e.g., a piezo element or piezoelectric bimorph.

When a swing motion in the vertical direction occurs due to insufficient precision of a mechanism system (not shown) for driving the convergence angle motor, encoders for respectively detecting inclination angles (elevation angles) $\Delta\phi_1$, in the vertical direction, of the right and left side imaging systems 10_R and 10_L, and vertical direction drive systems for respectively moving the right and left side image sensors 12_R and 12_L in the vertical direction may be separately arranged. Thus, when the right and left side image sensors 12_R and 12_L are moved in the vertical direction according to the detected inclination angles $\Delta\phi_1$ in the vertical direction, mis-registration amounts Δb, in the vertical direction, of images obtained by the right and left imaging systems 10_R and 10_L can be similarly corrected to be equal to or smaller than an allowable value Δb_0. At this time, the mis-registration amount Δb, in the vertical direction, of each image can be calculated by the following equation like in equation (18):

$$\Delta b = f \times (\beta - 1) \times \tan(\Delta\phi_1) \qquad (19)$$

For the following reasons, the mis-registration amounts Δb, in the vertical direction, of images may be corrected upon combination of coarse adjustment attained by the convergence angle motors 27_R and 27_L in the multi-lens imaging apparatus of the embodiment shown in Figs. 21A to 21C, and fine adjustment attained by the horizontal direction drive systems 243_R and 243_L in the multi-lens imaging apparatus of this embodiment:

(1) to prevent regions to be subjected to aberration correction of the right and left side imaging optical systems 11_R and 11_L from being increased very much; and

(2) to prevent the loads on the horizontal direction drive systems 243_R and 243_L from being increased.

Figs. 25A and 25B show a multi-lens imaging apparatus according to still another embodiment of the present invention.

In the multi-lens imaging apparatus of this embodiment, the right and left side image sensors 12_R and 12_L respectively comprise camera tubes, and the arrangement of the apparatus of this embodiment is substantially the same as that of the multi-lens imaging apparatus of the embodiment shown in Figs. 24A and 24B, except that camera tube electron beam scanning locus control drivers 251_R and 251_L are used in place of the horizontal direction drive systems 243_R and 243_L.

More specifically, in the multi-lens imaging apparatus of this embodiment, since the camera tubes read video signals by scanning electron beams, the scanning loci of the electron beams by the camera tubes are

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controlled by the camera tube electron beam scanning locus control drivers 251_R and 251_L in accordance with the mis-registration amounts Δa obtained by equation (18) above, thereby registering the images expressed by the video signals output from the right and left side image sensors 12_R and 12_L.

Figs. 26A and 26B show a multi-lens imaging apparatus according to still another embodiment of the present invention.

In the multi-lens imaging apparatus of this embodiment, the right and left side image sensors 12_R and 12_L respectively comprise solid-state imaging device, and the mis-registration amounts Δa of images obtained by the right and left imaging systems 10_R and 10_L are corrected to be equal to or smaller than the allowable value Δa_0 without using the horizontal direction drive systems 243_R and 243_L shown in Fig. 24B. The apparatus of this embodiment has the following differences from the multi-lens imaging apparatus of the embodiment shown in Figs. 24A and 24B.

(1) The apparatus of this embodiment does not include the horizontal direction drive systems 243_R and 243_L.

(2) The apparatus of this embodiment includes a correction conversion portion 261 and a second left side image memory 262 between the left side image memory 232_L and the synthesizing process circuit 233 (see Fig. 26B).

The operation of the multi-lens imaging apparatus of this embodiment will be described below.

The calculation control portion 244 receives the output signals from the rotational angle detecting means 28_R and 28_L, the zoom encoders 41_R and 41_L, and the focus encoders 42_R and 42_L, and calculates the mis-registration amounts Δa and Δb of images using equations (18) and (19). The correction conversion portion 261 converts the coordinates of image data output from the left side image memory 232_L in accordance with the mis-registration amount Δa calculated by the calculation control portion 244, and writes the converted image data in the second left side image memory 262. As a result, when the synthesizing process circuit 233 synthesizes the image data respectively output from the second left side image memory 262 and the right side image memory 232_R, a high-fine synthesized image signal can be obtained.

Note that the correction conversion portion 261 and a second left side image memory may be arranged between the right side image memory 232R and the synthesizing process circuit 233 in place of the correction conversion portion 261 and the second left side image memory 262. The left side image memory 232_L and the second left side image memory 262 may be replaced with a common one. Furthermore, when the coordinates of image data output from the left side image memory 232_L are converted, an interpolation calculation process of image data may be performed as needed.

In each of the multi-lens imaging apparatus of the embodiments shown in Figs. 21A to 26B according to the present invention, the mis-registration amounts Δa of images are calculated based on the output signals from the rotational angle detecting means 28_R and 28_L, the zoom encoders 41_R and 41_L, and the focus encoders 42_R and 42_L. Alternatively, the mis-registration amounts Δa of images may be calculated from image signals output from the right and left imaging systems 10_R and 10L. Such embodiments of multi-lens imaging apparatuses of the present invention will be described hereinafter.

Fig. 27 is a block diagram for explaining an operation of a correlation calculation process portion in a multi-lens imaging apparatus according to still another embodiment of the present invention.

The multi-lens imaging apparatus of this embodiment has the following differences from the multi-lens imaging apparatus of the embodiment shown in Figs. 26A and 26B.

(1) The apparatus of this embodiment includes a correlation calculation process portion 271 for performing a correlation calculation between image data output from the second left side image memory 262 and image data output from the right side image memory 232_R to obtain a correlation value δ_s. When the correlation value δ_s is equal to or larger than a predetermined value, the portion 271 calculates a new shift amount X so that the correlation value δ_s becomes equal to or smaller than the predetermined value, and outputs the calculated shift amount X to the correction conversion portion 261.

(2) When the correction conversion portion 261 writes image data output from the left side image memory 232_L in the second left side image memory 262, it shifts the coordinates of the image data in the horizontal and vertical directions by the shift amount X sent from the correlation calculation process portion 271.

The operation of the multi-lens imaging apparatus of this embodiment will be described below.

The correction conversion portion 261 shifts the coordinates of image data output from the left side image memory 232_L in the horizontal and vertical directions by a predetermined shift amount X (e.g., by one pixel each in the horizontal and vertical directions), and writes the coordinate-shifted image data in the second left side image memory 262. The correlation calculation process portion 271 performs a correlation calculation between image data output from the second left side image memory 262 and image data output from the right side image memory 232_R to obtain a correlation value δ_s. When the correlation value δ_s is

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equal to or larger than a predetermined value, the portion 271 calculates a new shift amount X so that the correlation value δ_a becomes equal to or smaller than the predetermined value, and outputs the calculated shift amount X to the correction conversion portion 261. The correction conversion portion 261 shifts the coordinates of image data output from the left side image memory 232_L in the horizontal and vertical directions by the new shift amount X, and writes the coordinate-shifted image data in the second left side image memory 262. Thereafter, the above-mentioned operations are repeated until the correlation value δ_a becomes equal to or smaller than the predetermined value. After the correlation value δ_a becomes equal to or smaller than the predetermined value, a synthesizing process circuit (not shown) synthesizes image data respectively output from the second left side image memory 262 and the right side image memory 232_R, thus obtaining a high-fine synthesized image signal.

In order to shorten the correlation calculation time in the correlation calculation process portion 271, for example, the correlation calculation may be performed using only image data at the central portion of a frame. As a correlation calculation method, a known matching method, gradient method, or the like may be used.

Since a finally obtained shift amount X_0 indicates the mis-registration amount Δa of a image, the correlation calculation process portion 271 may calculate a correction signal corresponding to the finally obtained shift amount X_0, and the correction control methods described in the embodiments shown in Figs. 21A to 25B, i.e., the following control methods may be executed:

(1) convergence angle control

(2) correction drive control using drive systems capable of shifting the image sensors in the horizontal and vertical directions

(3) correction control for changing the electron beam scanning loci

The above-mentioned multi-lens imaging apparatus of the embodiment shown in Fig. 27 executes correction control of the mis-registration amounts Δa of images caused by convergence angle errors using the image signals output from the right and left side imaging systems 10_R and 10_L. However, the correction control of the mis-registration amounts Δa of images caused by a difference between the image formation magnifications of the right and left imaging optical systems 10_R and 10_L may be executed using the image signals output from the right and left imaging systems 10_R and 10_L. A multi-lens imaging apparatus according to such an embodiment of the present invention will be described below.

Fig. 28 is a block diagram for explaining an operation of a magnification correlation calculation process portion in a multi-lens imaging apparatus according to still another embodiment of the present invention.

The multi-lens imaging apparatus of this embodiment has substantially the same arrangement as that of the multi-lens imaging apparatus of the embodiment shown in Fig. 27, except that the apparatus of this embodiment includes a magnification correlation calculation process portion 281, a calculation process portion 282, and a third left side image memory 283.

The operation of multi-lens imaging apparatus of this embodiment will be described below.

Assume that the central positions of images obtained by the right and left side imaging systems 10_R and 10_L are registered with each other like in the multi-lens imaging apparatus of the embodiment shown in Fig. 27.

The calculation process portion 282 converts the coordinates of image data output from the left side image memory 232_L by multiplying the coordinates with a constant k proportional to the distance from the center of the frame, and writes the coordinate-converted image data in the third left side image memory 283. The magnification correlation calculation process portion 281 executes a correlation calculation between image data output from the third left side image memory 283 and image data output from the right side image memory 232_R to obtain a correlation value δ_s. When the correlation value δ_s is equal to or larger than a predetermined value, the portion 281 calculates a new constant k, so that the correlation value δ_s becomes equal to or smaller than the predetermined value, and outputs the constant to the calculation process portion 282. The calculation process portion 282 converts the coordinates of image data output from the left side image memory 232_L by multiplying the coordinates with the new constant k, and writes the coordinate-converted image data in the third left side image memory 283. Thereafter, the above-mentioned operations are repeated until the correlation value δ_s becomes equal to or smaller than the predetermined value. After the correlation value δ_s becomes equal to or smaller than the predetermined value, a synthesizing process circuit (not shown) synthesizes image data respectively output from the second left side image memory 262 and the right side image memory 232 thus obtaining a high-fine synthesized image signal from which the mis-registration amounts of images caused by a difference between the image formation magnifications of the right and left imaging optical systems 11_R and 11_L are corrected.

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Since a finally obtained constant k_0 indicates the ratio of image formation magnifications of the right and left imaging optical systems 11_R and 11_L, the magnification correlation calculation process portion 281 may calculate a correction signal according to the finally obtained constant k_0, and may execute the correction control methods described in the embodiments shown in Figs. 21A to 25B.

5   In order to shorten the correlation calculation time of the magnification correlation calculation process portion 281, the correlation calculation may be executed using only image signals in a hatched region (a region obtained by narrowing a horizontal process portion) having as its center a line Y-Y' passing through a point O on the object surface 2 and perpendicular to the plane including two optical axes L_R and L_L, as shown in Fig. 29. Since this region has symmetricity from the arrangement conditions of the right and left

10   side imaging optical systems 11_R and 11_L, and suffers from a common image distortion, a difference between the image formation magnifications can be easily calculated.

In order to shorten the correlation calculation time of the magnification correlation calculation process portion 281, a positional deviation correlation in the vertical direction may be calculated by the method described in the embodiment shown in Figs. 26A and 26B using only image signals in two upper and lower

15   hatched regions which have as their center a line Y-Y' passing through the point O on the object surface 2 and perpendicular to the plane including two optical axes L_R and L_L, and which are separated from the point O, as shown in Fig. 30. When representative points of these regions are represented by Q and R, and when images of these representative points Q and R on the left side image sensor 12_L are represented by Q_L' and R_L' and images of these representative points Q and R on the right side image sensor 12_R are

20   represented by Q_R' and R_R', a ratio of a line $Q_L' - R_L'$ to a line Q_R' and R_R' is calculated to obtain the final constant k_0. This technique utilizes the fact that the detection sensitivity of the difference between the image formation magnifications can be improved toward the periphery of the frame, and the fact that the difference between the image formation magnifications can be regarded as a positional deviation in a small region.

25   The final constant k_0 is obtained as described above, and the following correction control can be made on the basis of this constant k_0.

(1) When the zoom motors 25_R and 25_L have response characteristics necessary for correcting the mis-registration amounts of images caused by the difference between the image formation magnifications to be equal to or smaller than a predetermined value (allowable value), servo control is executed by

30   supplying a correction signal to one or both of the zoom motors 25_R and 25_L.

(2) When it is difficult for the zoom motors 25_R and 25_L to obtain response characteristics necessary for correcting the mis-registration amounts due to the influence of the non-sensitive bands or the like, correction control by changing the scanning loci of the electron beams or correction control by converting the coordinates of the image memory is suitably executed. In this case, an interpolation

35   calculation process of image data may be performed as needed.

Each of the multi-lens imaging apparatuses according to the above-mentioned embodiments of the present invention comprises two imaging systems. However, the present invention can also be applied to an apparatus using three or more imaging systems.

An embodiment of an apparatus for displaying images while partially overlapping image fields using a

40   plurality of imaging systems, e.g., for obtaining a panoramic image or a 3D-2D mixed image is disclosed.

Fig. 31 shows the basic arrangement of a panoramic multi-lens imaging system according to the present invention. The system includes a common object surface 1, and first and second imaging optical systems 102 and 202 having equivalent specifications, and normally comprising zoom lenses. The system also includes image sensors 103 and 203 similarly having equivalent specifications. Each of the image

45   sensors 103 and 203 comprises a camera tube such as a saticon or a solid state imaging element such as a CCD. (Although Fig. 31 illustrates a single-sensor type (or single-tube type) image sensor for the sake of simplicity, versatility will not be disturbed even when a two-sensor type (two-tube type) image sensor or three-sensor type (three-tube type) image sensor via a color separation system is used.) Optical axes 101 and 201 of these image sensors are arranged to be inclined through about θ symmetrically about a normal

50   0-0' to the object surface 1 so as to satisfy a condition that image fields to be picked up by these sensors overlap each other by a predetermined amount. Note that 2θ will be referred to as the convergence angle, and is changed according to the image formation magnifications of the imaging optical systems (the object distances and the focal lengths of photographing lenses).

Fig. 32 shows the detailed arrangement of the imaging optical systems and the image sensors. In Fig.

55   32, a support structure such as a lens barrel is not shown.

The first and second imaging optical systems 102 and 202 are respectively constituted by lens groups 102a, 102b, 102c, and 102d, and lens groups 202a, 202b, 202c, and 202d. In particular, the lens groups 102b and 202b are zoom lens groups, and the lens groups 102d and 202d are focus lens groups. The zoom

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lens groups 102b and 202b are respectively driven by drive systems (zoom motors) 106 and 206, and similarly, the focus lens groups 102d and 202d are respectively driven by drive systems (focus motors) 107 and 207. Encoders (zoom encoders) 108 and 208 are provided to the zoom lens groups 102b and 202b of the imaging optical systems so as to obtain position information, in the optical axis direction, of the
5　corresponding lens groups. Focal lengths f of the imaging optical systems 102 and 202 can be obtained based on signals output from the encoders 108 and 208. Note that the lens groups 102d and 202d also have a function of compensating for image surface movement upon movement of the zoom lens groups in addition to the focus function. Since the arrangement of the zoom lens is well known, a detailed description thereof will be omitted.

10　　　Encoders (focus encoders) 109 and 209 are provided to the focus lens groups 102d and 202d of the imaging optical systems so as to obtain position information, in the optical axis direction, of the corresponding lens groups. These encoders may comprise, e.g., externally attached members such as potentiometers, or may comprise systems such as pulse motors for detecting the position information, in the optical axis direction, of the lens by the drive systems themselves according to their drive method. The system of this
15　embodiment further includes mechanism systems (not shown) for integrally rotating the optical system 102 and the image sensor 103, and the optical system 202 and the image sensor 203 in opposite directions by the same · amount in planes respectively including optical axes 101 and 201, and drive systems (convergence angle motors) 104 and 204 for attaining such rotations. The system also includes rotational angle information detecting means 105 and 205. These means may comprise, e.g., externally attached
20　members such as rotary encoders, or may comprise systems such as pulse motors for detecting the position information, in the optical axis direction, of angle information by the drive systems themselves according to their drive method.

　　　A method of obtaining mis-registration amounts on the basis of image signals will be described below with reference to Figs. 33 and 34. Image memories 111 and 211 temporarily store signals of the overlapping
25　portion of image signals 110 and 210. Assume that image data are mis-registered due to a deviation in convergence angle. A horizontal image shift process portion 20 shifts the coordinates of image data in the image memory 111 in the horizontal direction by a predetermined amount X (e.g., one pixel), and writes the shifted image data in a image memory 112. Furthermore, control for calculating a difference δ_s between the contents of the image memories 112 and 211 is performed using a correlation calculation process portion
30　21 including a subtraction calculation process circuit and the like while sequentially changing the shift amount X so as to obtain a shift amount X_0 for minimizing the difference δ_s. At this time, the shift amount X_0 is normally obtained by an interpolation calculation process by, e.g., approximating the relationship between the difference δ_s and the shift amount X by, e.g., a function.

　　　In order to shorten the correlation calculation time, a method using only image data at the central
35　portion of the frame of the overlapping portion, i.e., a region which includes a point O on the object surface 1 and whose vertical and horizontal widths are shortened is effective. Alternatively, coarse adjustment may be attained by commonly using the encoders 105 and 205 for outputting convergence angle information, and fine adjustment may be attained by the above-mentioned detection using the image signals, so as to further reduce the area of a region to be subjected to a correlation calculation. The correlation calculation
40　method described here is normally called a matching method. However, the present invention is not particularly limited to this method, and other methods such as a gradient method may be used.

　　　The shift amount X_0 corresponding to the minimum value indicates a relative mis-registration amount $\Delta y'$ itself of a image output from each imaging system, which mis-registration occurs due to a deviation of the optical axis 101 or 201 (Fig. 31) from an ideal optical axis. Therefore, convergence angle correction
45　control is performed using a correction signal 10 for canceling the mis-registration amount $\Delta y'$ of the image. The method of obtaining the mis-registration amount will be described below.

　　　Assume that an imaging operation is performed while the convergence angle has a deviation from a predetermined value, i.e., the optical axis 101 or 201 has an angular deviation $\Delta \theta 1$ or $\Delta \theta 2$ with respect to an axis having a predetermined angle θ. Under this assumption, the relationship between the angular deviation
50　$\Delta \theta 1$ or $\Delta \theta 2$ and the mis-registration amount $\Delta y'$ of a image will be described below. For the sake of simplicity, a mis-registration amount $\Delta y'$ of a image output from each imaging system, which amount is generated since the optical axis 101 is deviated to an axis 101', as shown in Fig. 34, will be described below. The mis-registration amount with respect to the optical axis 201 can be obtained by the same equations, as is obvious to those who are skilled in the art from the arrangement of the optical systems, and
55　even when both the optical axes 101 and 201 have deviations, the mis-registration amount can be obtained as a sum of the two deviations. Therefore, a method of obtaining the mis-registration amount with respect to one optical axis will be described below, and a description of the method for the other axis will be omitted. Note that reference symbols shown in Fig. 34 are used. Furthermore, under an assumption that $\Delta \theta 1$ is very

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small, geometrically, we have:

$$S_0 \tan\Delta\theta1 = \Delta y \cdot \cos\theta \qquad (1)$$

5   where Δy is the deviation (PP' in Fig. 34), generated in the object surface, of an intersection P of the optical axis 101 and the object surface 1 from a predetermined value, and S_0 is the distance from the front-side principal point of the imaging optical system (lens) 102 to an object (similarly, S_0' is the distance from the rear-side principal point to the image surface). If the image formation magnification of the imaging optical system 102 is represented by β, the magnification β can be expressed from its definition by:

10

$$\beta = \Delta y'/\Delta y \qquad (2)$$

If the focal length of the imaging system (lens) is represented by f, we have:

15 . $$S_0 = f(\beta - 1)/\beta \qquad (3)$$

From equations (1), (2), and (3), the mis-registration amount $\Delta y'$ is given by:

$$\Delta y' = \tan\Delta\theta1 \cdot f((\beta - 1)/\cos\theta \qquad (4)$$
20

The zoom lens group 102b of the imaging optical system shown in Fig. 32 is provided with the encoder (zoom encoder) 108 for obtaining position information, in the optical axis direction, of the lens group, and the focal length f of the imaging optical system 102 can be obtained based on a signal output from the encoder 108. Similarly, the focus lens group 102d of the imaging optical system is provided with the

25 encoder (focus encoder) 109 for obtaining position information, in the optical axis direction, of the lens group, and the image formation magnification β of the imaging optical system 102 can be obtained based on both the signals from the zoom encoder 108 and the focus encoder 109. Assume that the focal lengths f and the image formation magnifications β of the two imaging optical systems 102 and 202 are caused to always coincide with each other by separately controlling the drive systems 105, 107, 206, and 207 on the

30 basis of the signals from the encoders 108, 109, 208, and 209. As described above, the mis-registration amount $\Delta y'$ of a image is obtained by a image signal process system, and the convergence angle 2θ, the focal length f, and the image formation magnification β are obtained by the encoders provided to each mechanism system. Based on these signals, a calculation control portion 22 obtains all the parameters except for $\Delta\theta1$ in equation (4).

35 The calculated angular deviations $\Delta\theta1$ and $\Delta\theta2$ are supplied to a convergence angle control portion 23. Note that the convergence angle motors 104 and 204 have sufficient response performance for angular precision necessary for correcting $\Delta y'$ to be equal to or smaller than a predetermined value (allowable value) $\Delta y0'$. The control portion 23 supplies $\Delta\theta1$ to the convergence angle motor 104 as a correction signal, and supplies $\Delta\theta2$ to the convergence angle motor 204 as a direct control target value. Alternatively, the

40 sum of $\Delta\theta1$ and $\Delta\theta2$ may be supplied to one of the convergence angle motors 104 and 204. Fig. 35 shows the flow of these signals.

In this manner, after the mis-registration amounts of the image signals 110 and 210 output from the corresponding imaging systems are mechanically corrected to be equal to or smaller than the predetermined value (allowable value) $\Delta y0'$, images of the overlapping portion are subjected to a joint process, and

45 thereafter, the image signals 110 can be synthesized to a single image signal 11 using, e.g., the image memories 111 and 211, an addition process circuit 24, and the like. Fig. 36 shows the flow of these signals. When such processes are sequentially performed as needed, a good panoramic image can always be obtained.

A panoramic image is generally an image corresponding to a short focal length. However, as can be

50 understood from equation (4), when the focal length f of the imaging optical system is large, or when the allowable value of the mis-registration amount of a image is small, the correction signals $\Delta\theta1$ and $\Delta\theta2$ also assume small values (on the order of several seconds), and it is difficult to obtain angular response performance necessary for correcting the mis-registration under the influence of, e.g., non-sensitive bands of the convergence angle motors 104 and 204. In this case, a method of correcting the mis-registration

55 amount of a image output from each imaging system by a means other than the convergence angle motor 104 or 204 is effective. Such an embodiment will be described below. The basic arrangement of the embodiment shown in Fig. 37 is substantially the same as that of the embodiment shown in Fig. 32, except that precision correction means 103a and 203a are added.

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The first and second imaging optical systems 102 and 202 are respectively constituted by lens groups 102a, 102b, 102c, and 102d, and lens groups 202a, 202b, 202c, and 202d. In particular, the lens groups 102b and 202b are zoom lens groups, and the lens groups 102d and 202d are focus lens groups. The zoom lens groups 102b and 202b are respectively driven by drive systems (zoom motors) 106 and 206, and
5 similarly, the focus lens groups 102d and 202d are respectively driven by drive systems (focus motors) 107 and 207. Encoders (zoom encoders) 108 and 208 are provided to the zoom lens groups 102b and 202b of the imaging optical systems so as to obtain position information, in the optical axis direction, of the corresponding lens groups. Similarly, encoders (focus encoders) 109 and 209 are provided to the focus lens groups 102d and 202d of the imaging optical systems so as to obtain position information, in the optical
10 axis direction, of the corresponding lens groups. These encoders may comprise, e.g., externally attached members such as potentiometers, or may comprise systems such as pulse motors for detecting the position information, in the optical axis direction, of the lens by the drive systems themselves according to their drive method. The system of this embodiment further includes mechanism systems (not shown) for integrally rotating the optical system 102 and the image sensor 103, and the optical system 202 and the
15 image sensor 203 in opposite directions by the same amount in planes respectively including optical axes 101 and 201, and drive systems (convergence angle motors) 104 and 204 for attaining such rotations. The system also includes rotational angle information detecting means 105 and 205. These means may comprise, e.g., externally attached members such as rotary encoders, or may comprise systems such as pulse motors for detecting the position information, in the optical axis direction, of angle information by the
20 drive systems themselves according to their drive method. However, since the above-mentioned encoders are used for the auxiliary purpose, they are not always necessary in this embodiment.

As has been described above with reference to Fig. 33, image memories 111 and 211 temporarily store signals of the overlapping portion of image signals 110 and 210. A horizontal image shift process portion 20 shifts the coordinates of image data in the image memory 111 in the horizontal direction by a predeter-
25 mined amount X (e.g., one pixel), and writes the shifted image data in a image memory 112. Furthermore, control for calculating a difference δ_s between the contents of the image memories 112 and 211 is performed using a correlation calculation process portion 21 including a subtraction calculation process circuit and the like while sequentially changing the shift amount X so as to obtain a shift amount X_0 for minimizing the difference δ_s. At this time, the shift amount X_0 may be obtained by an interpolation
30 calculation process by, e.g., approximating the relationship between the difference δ_s and the shift amount X by, e.g., a function. When a swing motion in the vertical direction occurs as well due to insufficient precision of the mechanism system for driving the convergence angle motors, the same process as that for the horizontal direction may be performed for the vertical direction, and a two-dimensional (plane) mis-registration amount can be obtained. Note that a mis-registration amount $\Delta y'$ (vertical) of a image in the
35 vertical direction is given by:

$$\Delta y' \text{ (vertical)} = \tan\Delta\theta 1 \cdot f(\beta - 1) \qquad (5)$$

In order to shorten the correlation calculation time, a method using only image data at the central portion of
40 the frame of the overlapping portion, i.e., a region which includes a point O on the object surface 1 and whose vertical and horizontal widths are shortened is effective. Alternatively, coarse adjustment may be attained by commonly using the encoders 105 and 205 for outputting convergence angle information, and fine adjustment may be attained by the above-mentioned detection using the image signals, so as to further reduce the area of a region to be subjected to a correlation calculation. The correlation calculation method
45 described here is normally called a matching method. However, the present invention is not particularly limited to this method, and other methods such as a gradient method may be used. The shift amount X_0 corresponding to the minimum value indicates a relative mis-registration amount $\Delta y'$ itself of a image output from each imaging system, which mis-registration occurs due to a deviation of the optical axis 101 or 201.

Therefore, in this embodiment, correction control of the positions in a plane of the sensors is performed
50 using a correction signal 10 according to the mis-registration amount $\Delta y'$ of a image. More specifically, the image sensors 103 and 203 are provided with drive systems 103a and 203a capable of shifting the sensors in the horizontal and vertical directions. Signals calculated by a calculation control portion 22, which received various signals, are received by a sensor position control portion 25, and correction drive control is executed using the drive systems 103a and 203a. Each of the drive systems 103a and 203a comprises,
55 e.g., a piezo element or a piezoelectric bimorph. Fig. 38 shows the flow of these signals.

After the mis-registration amounts of the image signals 110 and 210 output from the imaging systems are corrected to be equal to or smaller than $\Delta y0'$ as a predetermined allowable value, two images can be synthesized using, e.g., image memories and an addition process circuit like in the above embodiment.

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Since the flow of signals in this synthesizing process portion is common to that shown in Fig. 36, its illustration will be omitted here.

The movable ranges of the drive systems 103a and 203a may be defined as follows. That is, in order to prevent a region to be subjected to aberration correction of the imaging optical system from being
5   increased very much, and to prevent the load on the specifications of the drive system from being increased, the convergence angle encoders 105 and 205 may also be used, and the correction amount may be classified into coarse and fine levels with reference to a predetermined level, so that coarse adjustment is attained by driving the convergence angle motors 104 and 204, and fine adjustment is attained by driving the drive systems 103a and 203a.

10   Fig. 39 shows still another embodiment of the present invention. In this embodiment, the image sensors 103 and 203 described in the embodiment shown in Fig. 37 are specified to camera tubes, and systems for driving the image sensors in the horizontal or vertical direction are not used. The arrangement except for the drive systems 103a and 203a and the method of obtaining the correction signal 10 are common to those in the above embodiment, and a detailed description thereof will be omitted.

15   In general, the camera tubes read image signals by scanning electron beams. Therefore, camera tube electron beam scanning locus control drivers 103b and 203b for controlling the scanning loci of electron beams upon reading of the image signals are provided. As described above, signals calculated by the calculation control portion 22 which received various signals are received by an electron beam scanning locus control portion 28, and correction control for shifting the scanning loci of electron beams using the
20   drivers 103b and 203b is executed. With this control, images defined by the image signals 110 and 210 output from the image sensors 103 and 203 can be registered. Fig. 40 shows the flow of these signals. Note that the above-mentioned technique for registering images by changing the scanning loci of electron beams is a general technique as DRC (Digital Registration Correction) in, e.g., a three-tube color television system. After the mis-registration amounts of the image signals 110 and 210 output from the imaging systems are
25   corrected to be equal to or smaller than a predetermined value (allowable value) $\Delta y0'$, two images can be synthesized using, e.g., image memories and an addition process circuit like in the above embodiment (since the flow of signals in this synthesizing process portion is common to that shown in Fig. 36, its illustration will be omitted here).

Fig. 41 shows still another embodiment of the present invention, wherein the image sensors comprise
30   solid-state imaging device in place of the camera tubes, and systems for driving the sensors in the horizontal or vertical direction are not used. More specifically, in this embodiment, the image sensors 103 and 203 described in the embodiment shown in Fig. 39 specifically use solid-state imaging device. Therefore, the basic arrangement and the method of obtaining the correction signal 10 are common to those in the embodiments shown in Figs. 37 and 39, and a detailed description thereof will be omitted.

35   As shown in Fig. 42, signals calculated by a calculation control portion 22, which received various signals, are received by a image position control portion 27. Image memories 111 and 211 temporarily store image signals 110 and 210. Images defined by image data in this stage are not registered due to convergence angle errors. A correction conversion portion 28 converts the coordinates of image data. More specifically, the portion 28 executes control for shifting image data in the memory 111 by the calculated
40   mis-registration amount $\Delta y'$ of a image, and writing the shifted image data in a image memory 112. Although the image memories 112 and 111 are independently arranged for the sake of simplicity, a common memory may be used in place of these memories. When the coordinates of image data are shifted, a data interpolation calculation process may be performed as needed. In this embodiment, the coordinates of image data in the image memory 111 are shifted. Of course, the coordinates of image data in
45   the image memory 211 may be shifted. Then, two images can be synthesized based on image data in the image memories 112 and 211, as shown in Fig. 36, using, e.g., the image memories and an addition process circuit like in the above embodiment.

In the above embodiment, correction control of the mis-registration amounts $\Delta y'$ of images due to convergence angle errors is executed. In some cases, mis-registration amounts of images due to a
50   difference between image formation magnifications of imaging optical systems must also be taken into consideration.

Such mis-registration amounts can also be detected using image signals independently of the encoders 108 and 109 for obtaining position information, in the optical axis direction, of the lenses. Such an embodiment will be described below.

55   Fig. 43 shows still another embodiment of the present invention. The basic arrangement of this embodiment is the same as that of the embodiment shown in Fig. 37, and since the same reference numerals in Fig. 43 denote the same parts as in Fig. 37, a detailed description thereof will be omitted. The image memories 111 and 211 temporarily store image signals of the overlapping portions of the image

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signals 110 and 210. In this stage, images defined by image data are not registered due to a difference between the image formation magnifications of the imaging optical systems 102 and 202. In this case, assume that mis-registration amounts ($\Delta y'$ described above) of the central positions of two images have already been detected by, e.g., the method described in the embodiments shown in Figs. 32 to 42, and the central positions of the two images have been corrected.

As one method of a magnification correlation calculation process, the following method is known. More specifically, a magnification calculation process portion 29 converts the coordinates of image data in the image memory 111 by multiplying the coordinates with a constant k proportional to the distance from the center of the frame, and writes the coordinate-converted image data in a image memory 112. A difference δ_m between the contents of the image memories 112 and 211 is then calculated using a subtraction process circuit 30. The above-mentioned subtraction process is repeated while sequentially changing the constant k, thereby obtaining a constant k_0 corresponding to the minimum difference δ_m. Fig. 44 shows the flow of these signals. The constant k_0 represents the ratio of the image formation magnification of the imaging optical system 102 to that of the imaging optical system 202, and is defined as a correction signal 12.

Fig. 45 shows a method of shortening the above-mentioned magnification correlation process time.

In Fig. 45, only image signal portions 110a1 and 110a2, and 210a1 and 210a2 corresponding to two upper and lower regions 111A1 and 111A2 and two upper and lower regions 211A1 and 211A2, which portions respectively include a line Y-Y' passing through a point 0 on an object surface 1 and perpendicular to a plane including the optical axes 101 and 201, and are separated from the central portion 0, are used. Representative points of these regions on the object surface are represented by Q and R, and images of these points are represented by Q1', R1', Q2', and R2'. The positional deviation correlation, in the vertical direction of these points may be calculated by, e.g., the method described in the embodiments shown in Figs. 32 to 42, and the ratio of a length Q1'-R1' to a length Q2'-R2' may be calculated to obtain the constant k_0. This technique utilizes the fact that the detection sensitivity of the difference between the image formation magnifications can be improved toward the periphery of the frame, and the fact that the difference between the image formation magnifications can be regarded as a positional deviation in a small region. The constant k_0 is obtained, as described above, and the following correction control can be executed based on this constant.

More specifically, as a mis-registration correction method, when the zoom motors 106 and 206 have response performance necessary for obtaining a constant k_0 for correcting the mis-registration amounts of images caused by the difference between the image formation magnifications to be equal to or smaller than a predetermined value (allowable value), servo control is executed by supplying a correction signal to one or both of the zoom motors 106 and 206 so as to compensate for the magnifications.

When it is difficult for the zoom motors 106 and 206 to obtain response performance necessary for correcting the mis-registration amounts due to the influence of the non-sensitive bands, correction control by changing the scanning loci of the electron beams described above with reference to Fig. 39 or correction control by converting the coordinates of the image memory in the above embodiment may be suitably executed. In this case, upon coordinate conversion of the image memory, an interpolation calculation process of image data may be performed as needed.

As described above, an imaging apparatus which can obtain a panoramic image in which the boundary line is not conspicuous can be provided.

In the above embodiment, a relatively large aspect ratio is set. However, an image having a desired aspect ratio can be obtained by changing the convergence angle 2θ. Fig. 46 shows the principle of a synthesizing system. In Fig. 46, an image having a new aspect ratio is obtained by synthesizing images from right and left side imaging systems.

In this case, although the basic arrangement is the same as that shown in Fig. 31, the convergence angle 2θ is selected to be smaller than that of a panoramic image.

More specifically, the optical axes 101 and 201 shown in Fig. 31 are set to be symmetrically inclined through θ with respect to the normal O-O' to the object surface 1, so that two image fields overlap each other by a predetermined amount according to a selected aspect ratio of a frame.

For example, Fig. 47 shows a mode for converting an aspect ratio of 4 : 3 of images picked up by NTSC image sensors into an aspect ratio of 16 : 9 of an HD system.

Therefore, a desired aspect ratio is determined first, and the convergence angle corresponding to the determined aspect ratio is set by a setting means 115 (Fig. 48) by driving the convergence angle motors 104 and 204. Thereafter, the registration compensation method described in each of the above embodiments is applied to obtain a desired image.

The descriptions of the above embodiments have been made under an assumption that an object is a substantially flat one or can be regarded as a flat object. Next, an embodiment that can be applied to an

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object whose depth cannot be ignored will be described below.

Fig. 49 shows a basic arrangement of a multi-lens imaging system according to still another embodiment of the present invention. The system shown in Fig. 49 includes a common object surface 1, and first and second imaging optical systems 102 and 202 having equivalent specifications, and normally comprising 5 zoom lenses, as will be described later. Image sensors 103 and 203 similarly have equivalent specifications, and comprise camera tubes such as saticons, or solid-state imaging device such as CCDs. Although Fig. 49 illustrates a single-sensor type (or single-tube type) image sensor for the sake of simplicity, versatility will not be disturbed even when a two-sensor type (two-tube type) image sensor or three-sensor type (three-tube type) image sensor via a color separation system is used.

10   Optical axes 101 and 201 of these imaging optical systems are set to cross at a point O on the object surface 1 and to be symmetrically inclined through θ with respect to a normal O-O' to the object surface 1 while passing the point O. Note that 2θ is defined as the convergence angle, and imaging operations are performed by changing the convergence angle according to a change in object distance S.

Fig. 50 shows the detailed arrangement of the imaging optical systems 102 and 202, and Fig. 51 is a 15 block diagram showing functions of the members constituting the imaging optical systems. The first and second imaging optical systems 102 and 202 are respectively constituted by lens groups 102a, 102b, 102c, and 102d, and lens groups 202a, 202b, 202c, and 202d. In particular, the lens groups 102b and 202b are zoom lens groups, and the lens groups 102d and 202d are focus lens groups. The zoom lens groups 102b and 202b are respectively driven by drive systems (zoom motors) 106 and 206, and similarly, the focus lens 20 groups 102d and 202d are respectively driven by drive systems (focus motors) 107 and 207. The system of this embodiment further includes mechanism systems (not shown) for integrally rotating the optical system 102 and the image sensor 103, and the optical system 202 and the image sensor 203 in opposite directions by the same amount in planes respectively including optical axes 101 and 201, and drive systems (convergence angle motors) 104 and 204 for attaining such rotations.

25   Angle encoders (rotational angle detecting means) 105 and 205 respectively measure the rotational angles of the imaging optical systems 102 and 202. Zoom encoders 108 and 208 respectively measure the moving amounts of the zoom lens groups 102b and 202b to obtain zoom ratios. Focus encoders 109 and 209 measure the positions of the focus lens groups. Image signals 110 and 210 are output from the image sensors 103 and 203, and are stored in image memories 111 and 211.

30   Functions of a calculation control portion 12, a correlation calculation portion 13, and a correction calculation portion 14 will be described later.

Detection of position information of an object when imaging operations are performed in an arrangement shown in Fig. 52 will be described below.

As shown in Fig. 52, x-, y- and z-axes are defined to have the above-mentioned point O on the object 35 surface as an origin.

The intersections between the imaging optical systems 102 and 202 and their optical axes 101 and 201 are represented by Q_R and Q_L, the distance from the front-side principal point of the imaging optical system (lens) 102 or 202 to the above-mentioned point O is represented by S_0, and the distance from the rear-side principal point to the image sensor 103 or 203 is represented by S_0' - A method of obtaining coordinates P_2 40 (x_0, z_0) on the object surface 1 in the x-z plane shown in Fig. 53 will be briefly described below.

If the intersections between the imaging optical systems 102 and 202 and their optical axes 101 and 201 are respectively represented by QR $(x_1, -z_1)$ and Q_L $(-x_1, -z_1)$, the coordinates x_1 and z_1 can be geometrically expressed as follows using the imaging condition S_0 and the convergence angle θ:

45    $x_1 = S_0 \sin\theta$ (1-a)

$z_1 = S_0 \cos\theta$ (1-b)

Similarly, as for intersections O_R' $(x_2, -z_2)$ and O_L' $(-x_2, -z_2)$ between the image sensors 103 and 203 50 and the optical axes 101 and 201, their coordinates are expressed by:

$x_2 = (S_0 + S_0')\sin\theta$ (2-a)

$z_2 = (S_0 + S_0')\cos\theta$ (2-b)

55

As shown in Fig. 53, if image points on the image sensors 103 and 203 with respect to an object point P_2 (x_0, z_0) on an object are respectively represented by P_R' $(x_R, -z_R)$ and P_L' $(-x_L, -z_L)$, and the image heights on the image sensors 103 and 203 are respectively represented by X_R' and X_L', geometrically, we

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have:

$$x_R = (S_0 + S_0')\sin\theta - x_R'\cos\theta \quad \text{(3-a)}$$

$$z_R = (S_0 + S_0')\cos\theta + x_R'\sin\theta \quad \text{(3-b)}$$

$$x_L = (S_0 + S_0')\sin\theta + x_L'\cos\theta \quad \text{(3-c)}$$

$$z_L = (S_0 + S_0')\cos\theta - x_L'\sin\theta \quad \text{(3-d)}$$

At this time, if a line passing the points P_R' and Q_R is represented by $f_R(S_0, S_0', \theta, x_R')$, and a line passing the points P_L' and Q_L is represented by $f_L(S_0, S_0', \theta, x_L')$, the point $P_2(x_0, z_0)$ on the object surface corresponds to the coordinates of the intersection of these two lines according to the definition.

Also, as shown in Fig. 52, y_0 can be expressed as follows in association with the imaging optical system 102:

$$y_0 = y_R'S_R'/S_R \quad (4)$$

S_R is the distance from the object point $P_2(x_0, z_0)$ to the front-side principal point of the imaging optical system 102 in Fig. 53, and S_R' is the distance from the rear-side principal point of the imaging optical system 102 to the image pint P_R' on the image sensor 103 in Fig. 53.

At this time, a point $P(x_0, y_0, z_0)$ in Fig. 52 is defined by:

$$p = f(S_0, S_0', \theta, x_R', x_L', Y_{R(L)}') \quad (5)$$

That is, the point P is expressed by a function of imaging conditions (S_0, S_0', θ) and an output image $(x_R', x_L', y_{R(L)}')$ of each image sensor, and position information on the object surface can be obtained by detecting these parameters.

The method of obtaining parameters in the above-mentioned process will be described below with reference to Figs. 50 and 51. First, the convergence angle 2θ is detected by the rotational angle detecting means 105 and 205 such as rotary encoders. The encoders (zoom encoders) 108 and 208 for obtaining position information, in the optical axis direction, of the corresponding lens groups are used, and the focal lengths f of the imaging optical systems 102 and 202 are obtained based on the signals output from these encoders. Similarly, the encoders (focus encoders) 109 and 209 for obtaining position information, in the optical axis direction, of the corresponding lens groups are provided to the focus lens groups 102d and 202d of the imaging optical systems. These encoders may comprise, e.g., externally attached members such as potentiometers, or may comprise systems such as pulse motors for detecting the position information, in the optical axis direction, of the lens by the drive systems themselves according to their drive method. The calculation control portion 12 calculates the object distances S_0 to the imaging optical systems 102 and 202 on the basis of the signals from the focus encoders 109 and 209. Furthermore, the portion 12 calculates lens backs S_0' of the imaging optical systems 102 and 202 together with the focal lengths f of the imaging optical systems 102 and 202. Note that the focal lengths f and the lens backs S_0' of the two imaging optical systems 102 and 202 are caused to always coincide with each other by independently controlling the drive systems 106, 107, 206, and 207 on the basis of the signals from the encoders 108, 109, 208, and 209.

As described above, the calculation control portion 12 calculates S_0 (the distance from the front-side principal point of the imaging optical system (lens) to the intersection of the corresponding optical axis), S_0' (the distance from the rear-side principal point of the imaging optical system (lens) to the image surface), and θ (convergence angle) on the basis of the signals from the encoders 105, 108, 109, 205, 208, and 209. The image memories 111 and 211 temporarily store image signals 110 and 210.

The correlation calculation process portion 13 performs a correlation calculation about image data stored in the image memories 111 and 211. Figs. 54A and 54B show the principle of a correlation calculation process. In the process, as shown in Fig. 54B, a pixel data group 112 having pixel data R_{ij} at a point (x_{iR}', y_{jR}') as a center is defined as one block, and a correlation calculation is performed between this block and a corresponding image block on the image memory 211. Fig. 55 illustrates the relationship between a correlation value and an x' (y') axis coordinate in the correlation calculation in the horizontal and vertical directions. In Fig. 55, X_L' (y_L') corresponding to a maximum correlation value is obtained with a precision equal to or lower than the sampling pitch of the image sensor by, e.g., approximating the

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relationship near the correlation peak by a function. The block 112 is also defined for other pixel data R_{ij} on the image memory 111, and a similar calculation process is executed to obtain x_L' and y_L' for each pixel data.

The coordinates P_R (x_0, y_0, z_0) on the object surface corresponding to each pixel data R_{ij} on the image
5   sensor 103 can be calculated from the relationship given by equation (5) using the image information (x_{iR}', x_L', y_{jR}') obtained by these series of processes, and the imaging conditions (S_0, S_0', θ).

The same calculation process is executed for each pixel data L_{ij} (x_{iL}', Y_{jL}') of the image sensor 203 to obtain x_R' and y_R' for each pixel, and the coordinates P_L (x_0, y_0, z_0) on the object surface corresponding to each pixel data L_{ij} on the image sensor 203 are then calculated. Note that the coordinates P_R and P_L on the
10 object surface do not always coincide with each other.

The correction process portion 14 executes a process on the basis of the coordinates P_R and P_L obtained by the above-mentioned process. In the correction process portion 14, a desired view position is input. At this time, when the view position is input, as shown in Fig. 56, image points (x', y') corresponding to the coordinate values can be obtained as follows using the above-mentioned imaging conditions S_0 and
15 S_0' and the coordinates $P_{R(L)}$ (x_0, y_0, z_0) on the object surface:

$$x' = x_0 S_0'/(S_0 + z_0) \qquad (6\text{-}a)$$

$$y' = y_0 S_0'/(S_0 + z_0) \qquad (6\text{-}b)$$

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The coordinates ($x_{iR(L)}'$, $Y_{iR(L)}'$) on each image memory are coordinate-converted by a calculation process on the basis of equations (6-a) and (6-b), and the converted data are written in a image memory 15. The mis-registration amounts have been removed from the image data stored in the image memory 15, and the image data is ideally twice image data output from the image sensors 103 and 203. As a result, a high-fine
25 output image can be obtained.

The embodiment described above with reference to Fig. 49 and subsequent drawings can be applied to a panoramic image and images having various aspect ratios. In this case, since an operation for extracting corresponding points on at least partial regions of a plurality of images is required, the images must partially overlap each other. A plurality of imaging optical systems of every embodiment does not always lie
30 in the same mode. For a different purpose, a different mode imaging optical system is sometimes used.

With the above-mentioned arrangements of the present invention, the following effects can be expected.

Even when images obtained by imaging systems suffer from keystone distortions, the keystone distortions can be removed, and the images can be converted into desired images, thus obtaining a high-fine image free from keystone distortions.
35 Since at least one of a mechanism system or image process system is controlled so as to correct a mis-registration amount detected by a detecting means to be equal to or smaller than a predetermined value, images obtained by imaging systems can be registered and synthesized. For this reason, an apparatus which can obtain a high-fine image by picking up an image of a common object using a plurality of imaging systems can be provided.
40 Also, an apparatus capable of obtaining an image having very high image quality and a desired aspect ratio, and an apparatus capable of obtaining a panoramic image free from a conspicuous boundary line can be provided.

When a multi-lens imaging apparatus of the present invention is connected to a display device such as a CRT via an image process apparatus, it can be utilized as a high-performance panoramic TV system, a
45 3D TV system, an HDTV system, and the like. Similarly, when the apparatus of the present invention is connected to a recording apparatus via the image process apparatus, it can be utilized as a high-performance recording system.

This invention relates to a multi-lens imaging apparatus and, more particularly, to a multi-lens imaging apparatus for obtaining a single high-fine image by synthesizing a plurality of images obtained by picking
50 up an image of a common object using a plurality of imaging systems and to an apparatus which can provide an image having an aspect ratio different from that of an image obtained by a single imaging apparatus, especially, a panoramic image, by synthesizing a plurality of images using a plurality of imaging systems. This invention has as its object to obtain a high-fine image by synthesizing images from a plurality of imaging systems and, more specifically, to correct mis-registration such as keystone distortions
55 generated in the images.

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10. An apparatus according to claim 9, wherein said keystone distortion correction means corrects the keystone distortion with reference to focal lengths, image formation magnifications, and inclination angles of the optical axes with respect to an object surface of said plurality of imaging optical systems.

11. An apparatus according to claim 9, wherein said keystone distortion correction means executes a conversion process of images obtained by said plurality of imaging optical systems on the basis of focal lengths and image formation magnifications of said plurality of imaging optical systems using an arbitrary conversion variable so as to obtain a difference between the converted images, and corrects the keystone distortion using the conversion variable to minimize the difference between the images.

12. An apparatus according to claim 9, wherein said keystone distortion correction means detects a distortion amount of the keystone distortion using, as parameters which are focal lengths, image formation magnifications, and inclination angles of the optical axes with respect to an object surface of said plurality of imaging optical systems, calculates a difference between an image from which the keystone distortion is corrected according to the detected distortion amount and a desired image, and sets up the inclination angles to minimize the difference, thereby correcting the keystone distortion.

13. An apparatus according to claim 9, wherein said image sensing means comprise camera tubes.

14. An apparatus according to claim 9, wherein said image sensing means comprise solid-state imaging device.

15. A multi-lens imaging apparatus for picking up an image using a plurality of imaging optical systems while image fields at least partially overlap each other, comprising:

detection means for extracting image signals of the overlapping portion of images obtained from said plurality of imaging optical systems, and detecting a displacement amount of registration of the overlapping portion; and

correction means for correcting the displacement amount of registration to be less than a predetermined value according to a detection signal from said detection means.

16. An apparatus according to claim 15, further comprising image sensing means for sensing images from said plurality of imaging optical systems.

17. An apparatus according to claim 16, further comprising means for synthesizing a plurality of image signals output from said image sensing means.

18. An apparatus according to claim 15, further comprising convergence angle changing means for making an angle formed between optical axes of said plurality of imaging optical systems change.

19. A multi-lens imaging apparatus comprising:

a plurality of imaging optical systems;

means for detecting imaging conditions of said plurality of imaging optical systems;

image sensing means for sensing images of an object via said plurality of imaging optical systems;

means for detecting position information of the object from the image signals from said image sensing means; and

image synthesizing means for synthesizing the plurality of images on the basis of the imaging conditions and the position information so that corresponding points of the plurality of images coincide with each other.

20. An apparatus according to claim 19, wherein said image synthesizing means forms a synthesized image with reference to a predetermined view position.

21. A multi-lens imaging apparatus for picking up an image of a common object using a plurality of imaging optical systems, comprising:

image sensing means for sensing images of the object corresponding to said plurality of imaging optical systems;

detection means for detecting three-dimensional position information of a plurality of points in each of the images obtained by said image sensing means; and

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Claims

1. A multi-lens imaging apparatus comprising:
     a plurality of imaging optical systems;
     image sensing means for sensing images of an object corresponding to said plurality of imaging optical systems via said plurality of imaging optical systems;
   detection means for detecting displacement amounts of registration amounts of the images of the object obtained from said plurality of imaging optical systems;
     correction means for correcting the displacement amounts to be less than a predetermined value according to a detection signal from said detection means; and
     synthesizing means for synthesizing the images of the object.

2. An apparatus according to claim 1, wherein said detection means comprises:
     convergence angle detection means for detecting an angle defined between optical axes of said plurality of imaging optical systems;
     zoom encoders for detecting focal lengths of said imaging optical systems; and
     focus encoders for detecting object distances to said imaging optical systems.

3. An apparatus according to claim 2, wherein said image sensing means comprise camera tubes, and said apparatus further comprises correction signal generation means for generating a correction signal of the displacement amounts of registration on the basis of output signals from said convergence angle detection means, said zoom encoders, and said focus encoders, and camera tube electron beam scanning locus control drivers for controlling electron beams of said camera tubes on the basis of the correction signal.

4. An apparatus according to claim 2, wherein said image sensing means comprise solid-state image pickup elements, and said apparatus further comprises image memories for storing a plurality of image data from said solid-state image pickup elements, correction conversion means for obtaining the displacement amounts of registration of the plurality of image data, and executing coordinate conversion of the image data to cancel the displacement amounts of registration, and synthesizing process means for synthesizing the plurality of image data.

5. An apparatus according to claim 1, wherein optical axes of said plurality of image pickup optical systems are not parallel to each other, and the said displacements of registration are caused by keystone distortions of the images of the object.

6. An apparatus according to claim 1, wherein the displacements of registration are caused by a difference between image formation magnifications of said plurality of imaging optical systems, and said apparatus comprises a magnification correlation calculation process portion and a calculation process portion.

7. An apparatus according to claim 6, wherein said magnification correlation calculation process portion calculates positional deviations associated with distances from a center to corresponding positions on a plurality of frames, and inputs a constant for correcting the positional deviations to said calculation process portion.

8. An apparatus according to claim 7, wherein said magnification correlation calculation process portion executes a correlation calculation using image signals in a partial region having a line passing central portions of the plurality of frames and perpendicular to a plane including the optical axes of at least two of said imaging optical systems defined as a center.

9. A multi-lens imaging apparatus comprising:
     a plurality of imaging optical systems whose optical axes are not parallel to each other;
     image sensing means for sensing images of an object corresponding to said plurality of imaging optical systems via said plurality of imaging optical systems;
     keystone distortion correction means for correcting a keystone distortion generated in at least one image obtained through said image sensing means; and
     synthesizing means for synthesizing the plurality of images.

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synthesizing means for generating a synthesized image of the plurality of images on the basis of the position information.

22. An image recording system comprising:
a multi-lens imaging apparatus; and
a recording apparatus for executing an image process of an image signal from said multi-lens imaging apparatus, and recording the processed image signal, wherein
said multi-lens imaging apparatus includes:
a plurality of imaging optical systems;
image sensing means for sensing images of an object corresponding to said plurality of imaging optical systems via said plurality of imaging optical systems;
detection means for detecting displacement amounts of registration of the images of the object obtained from said plurality of imaging optical systems;
correction means for correcting the displacement amounts of registration to be less than a predetermined value according to a detection signal from said detection means; and
synthesizing means for synthesizing the images of the object.

23. A TV system comprising:
a multi-lens imaging apparatus;
an image process apparatus for synthesizing a plurality of image signals from said multi-lens imaging apparatus; and
a display apparatus for displaying an image according to an image signal from said image process apparatus,
said multi-lens imaging apparatus comprising:
a plurality of imaging optical systems;
image sensing means for sensing images of an object corresponding to said plurality of imaging optical systems via said plurality of imaging optical systems;
detection means for detecting mis-registration amounts of the images of the object obtained from said plurality of imaging optical systems;
correction means for correcting the displacement amounts of registration to be less than a predetermined value according to a detection signal from said detection means; and
synthesizing means for synthesizing the images of the object.
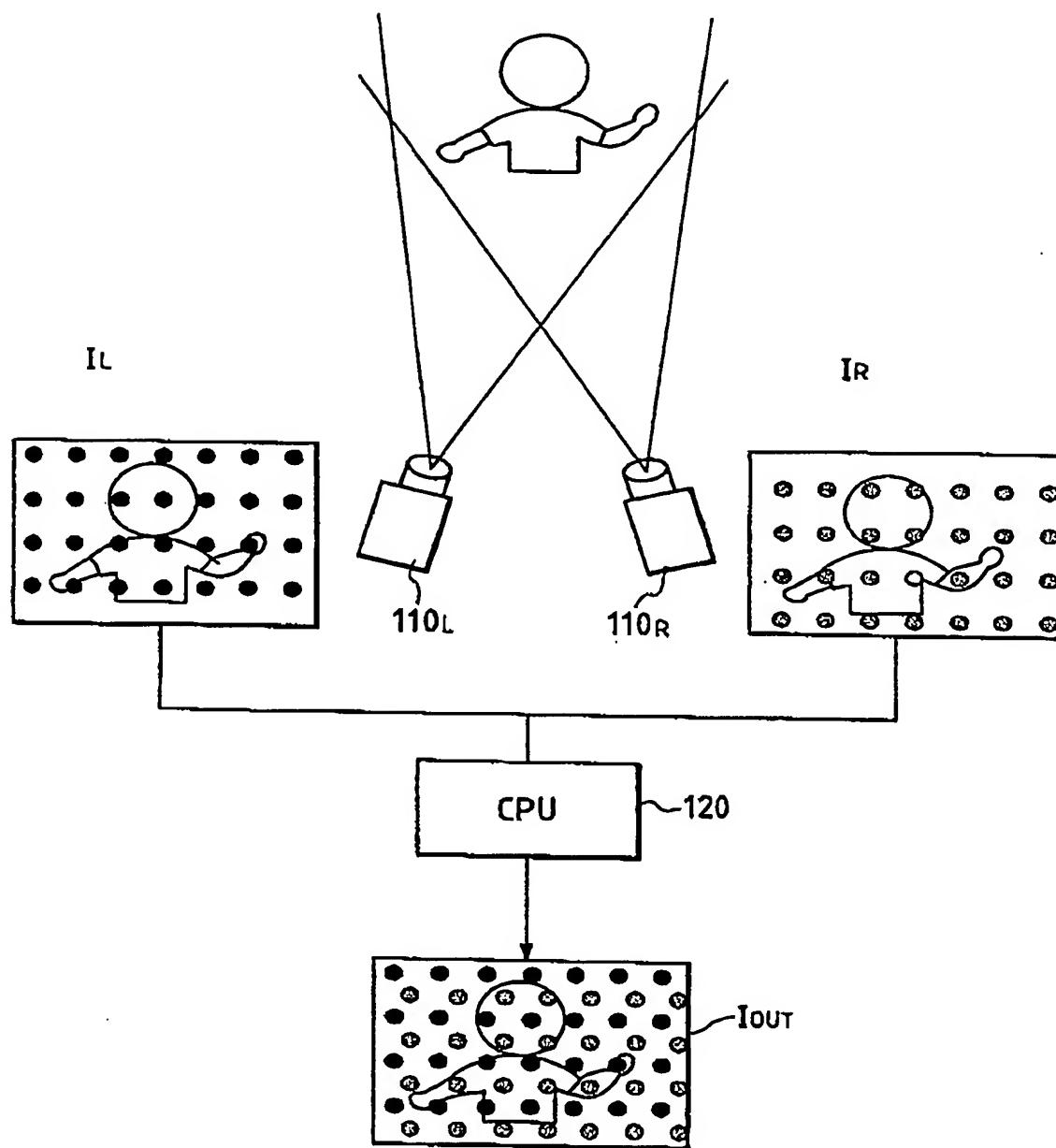
FIG. 1

FIG. 2
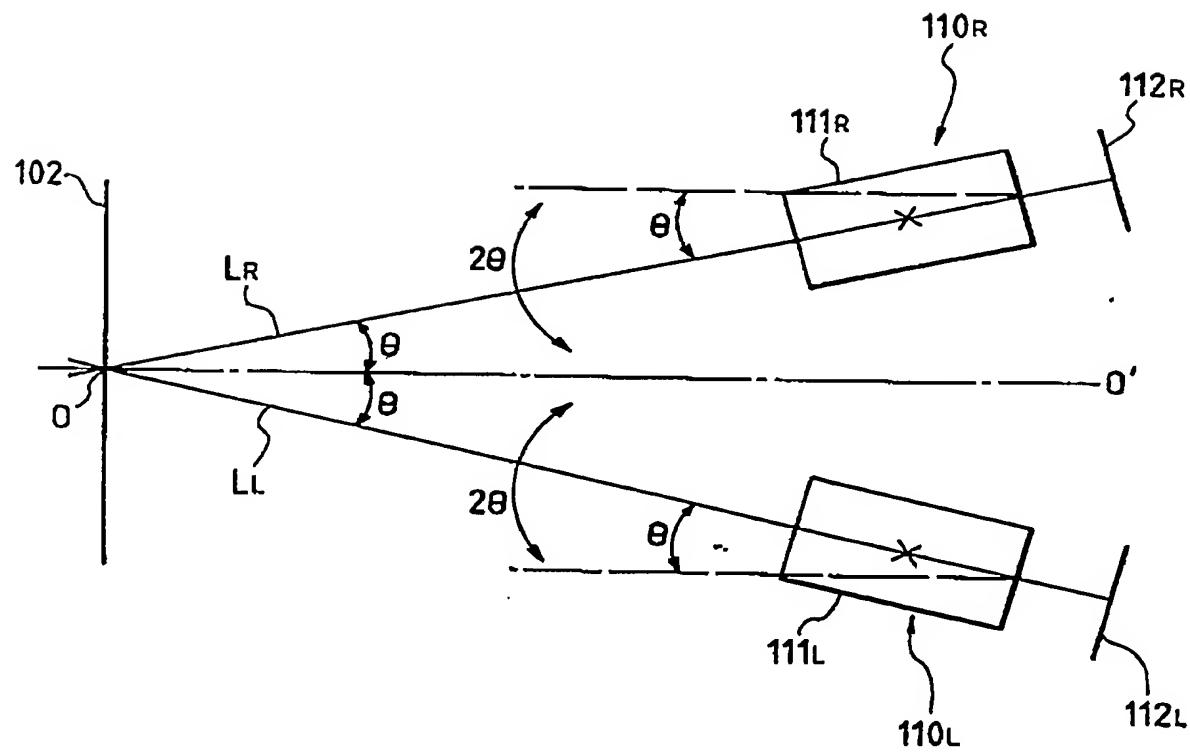
FIG. 3
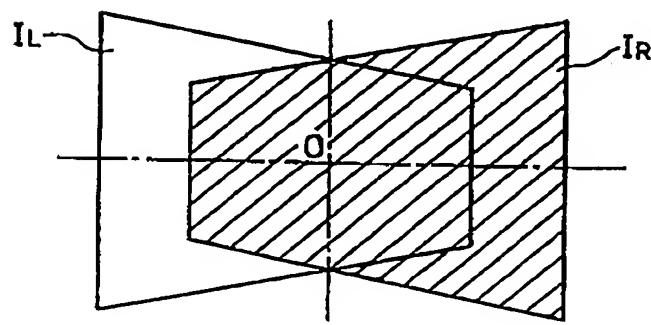
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FIG. 4A
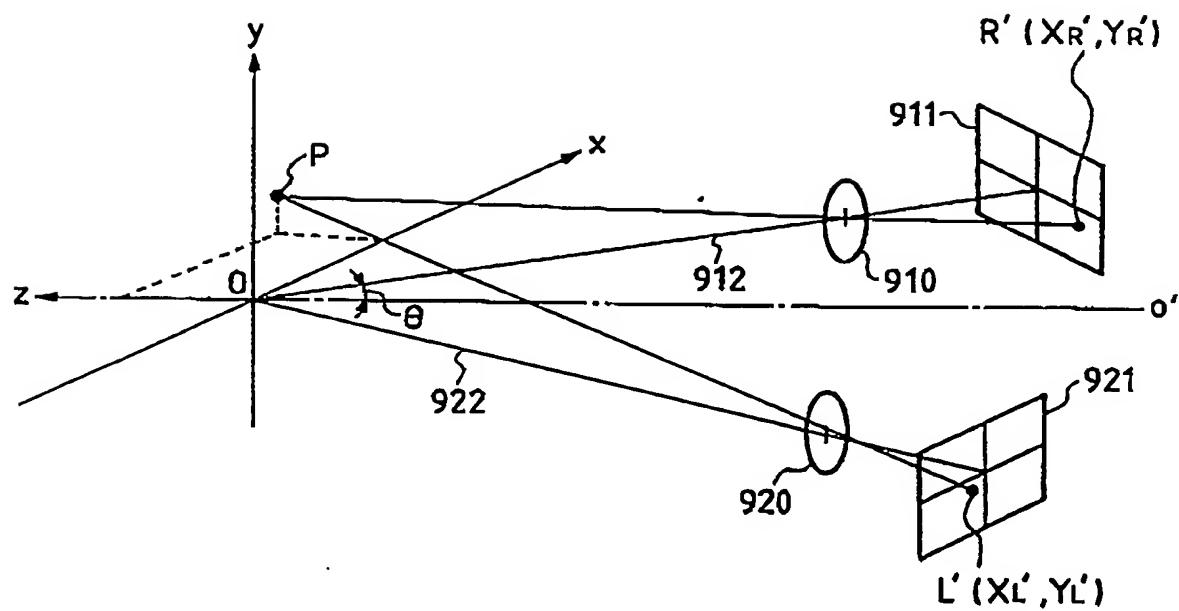
FIG. 4B

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FIG. 5A
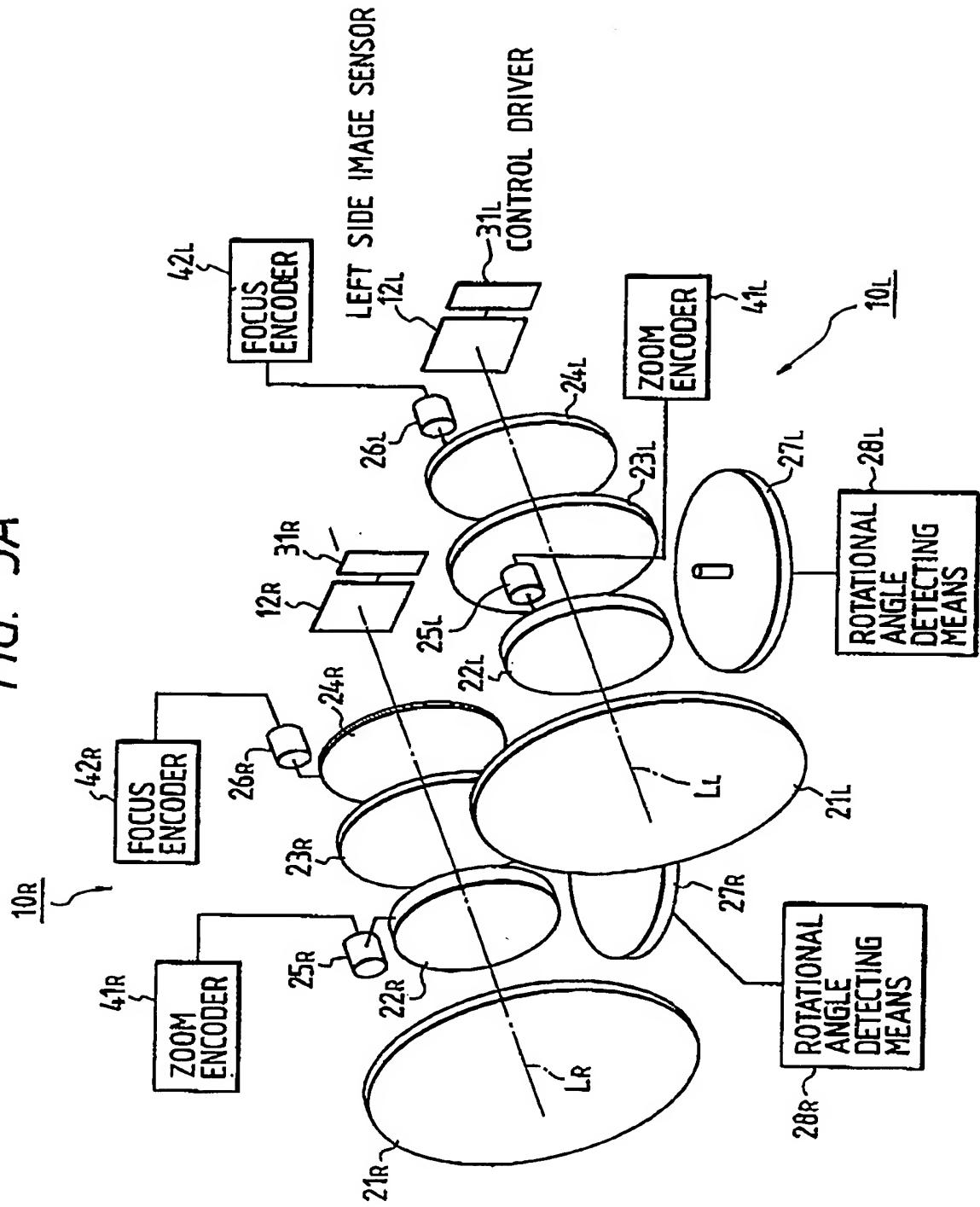
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FIG. 5B
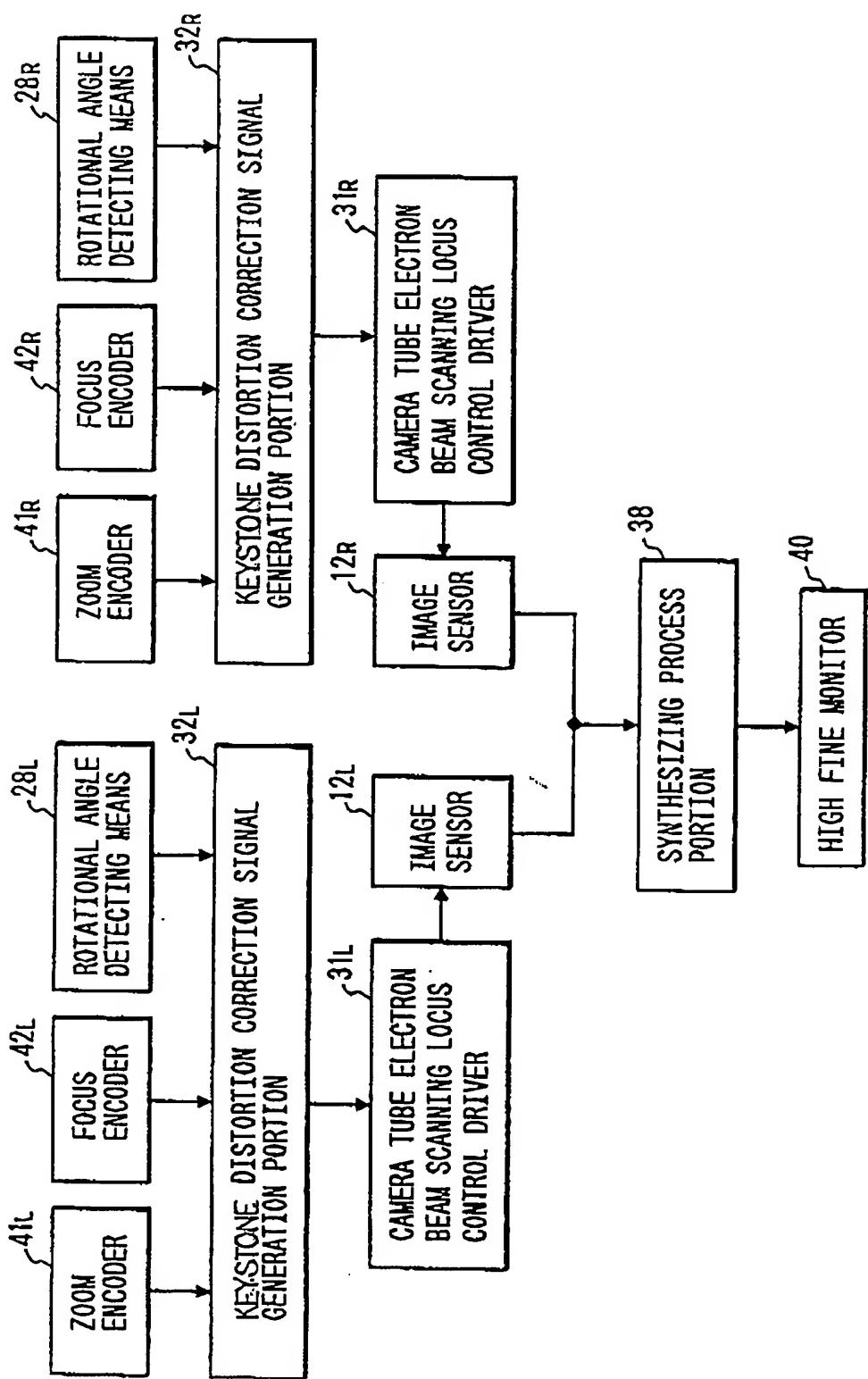
FIG. 6
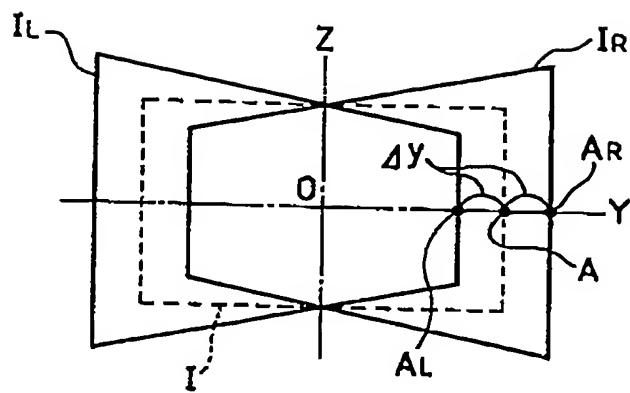
FIG. 7
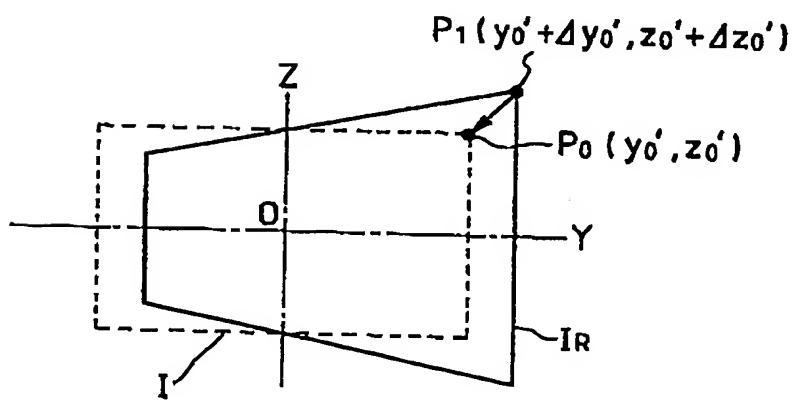
FIG. 8
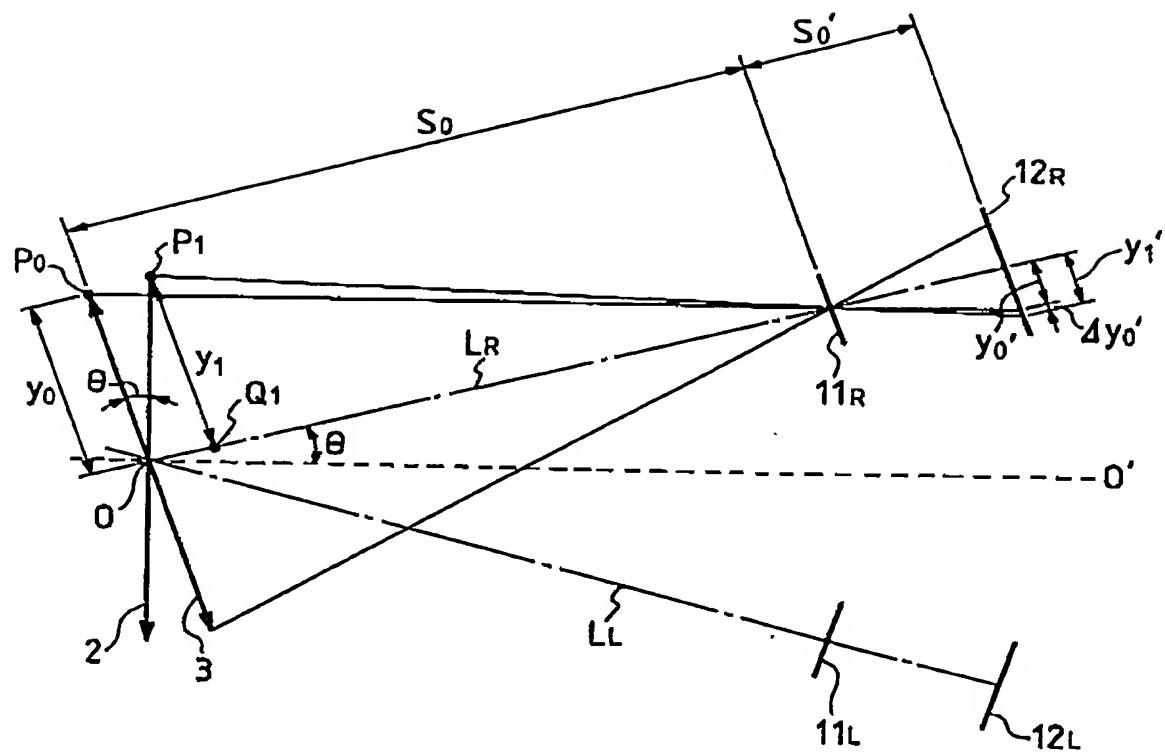
FIG. 9
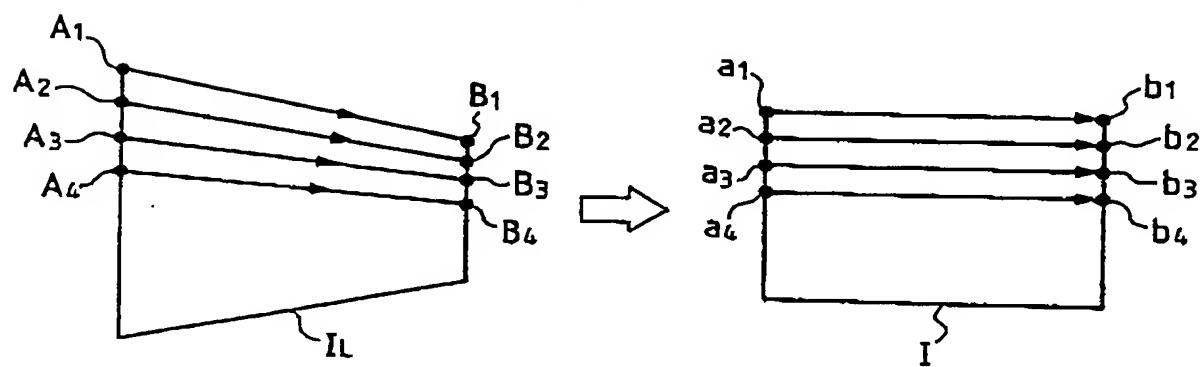
FIG. 10
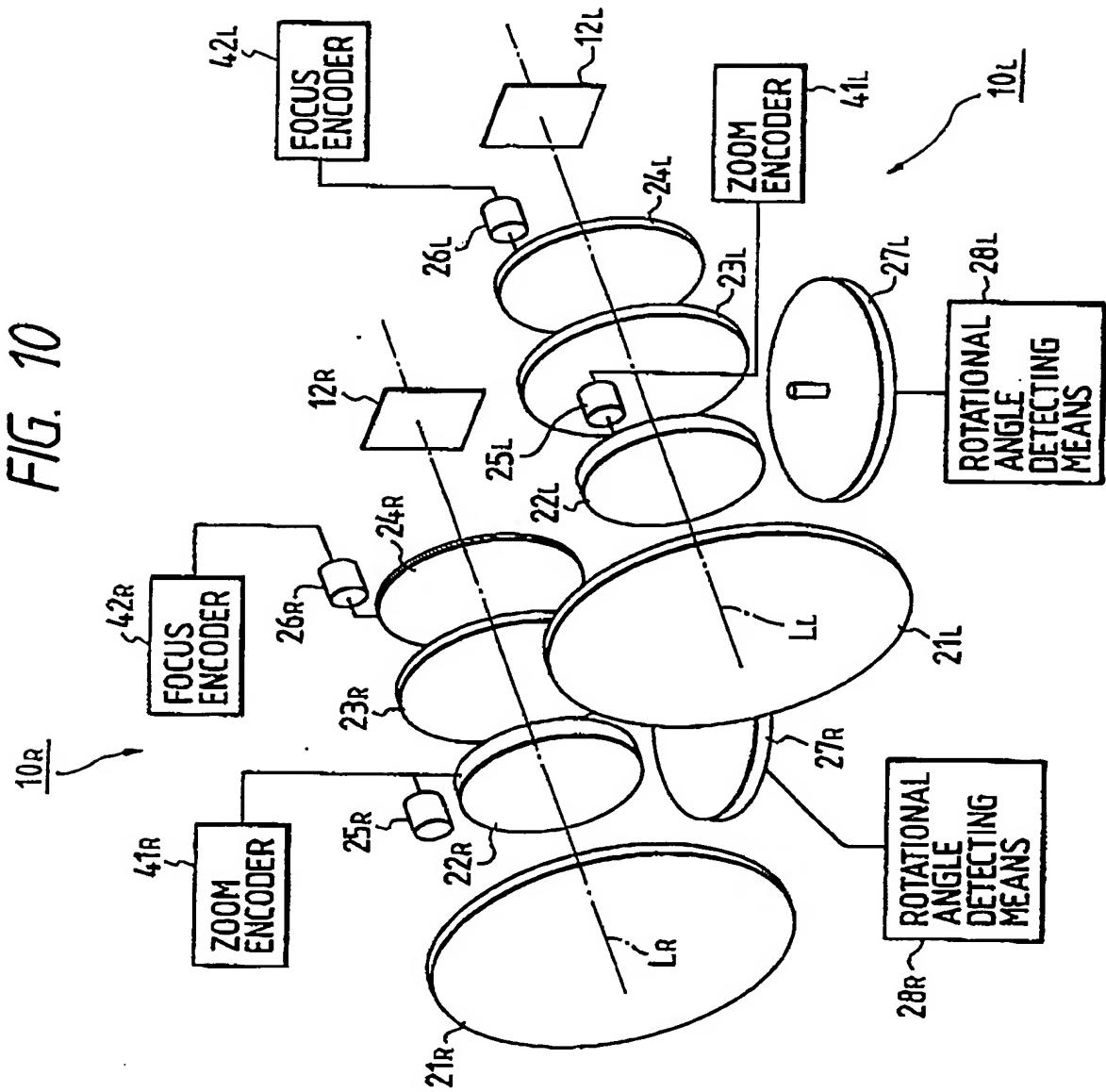
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FIG. 11

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FIG. 12

FOCUS ENCODER — 42L

12L

61L

ZOOM ENCODER — 41L

10L

24L

26L

23L

27L

28L

ROTATIONAL ANGLE DETECTING MEANS

12R

61R

25L

22L

LL

21L

24R

FOCUS ENCODER — 42R

26R

23R

10R

LR

41R

ZOOM ENCODER

25R

22R

27R

ROTATIONAL ANGLE DETECTING MEANS

28R

21R

40
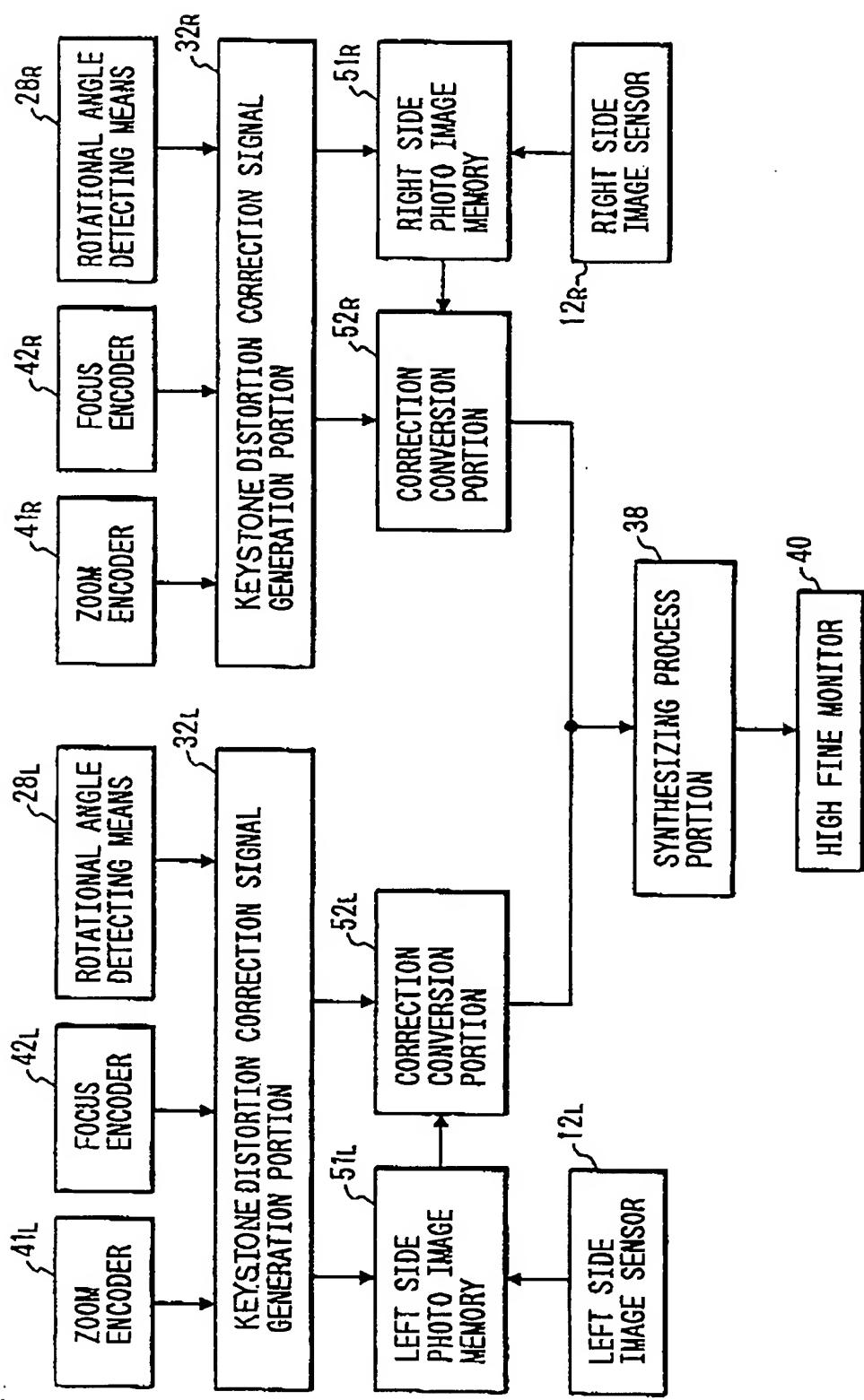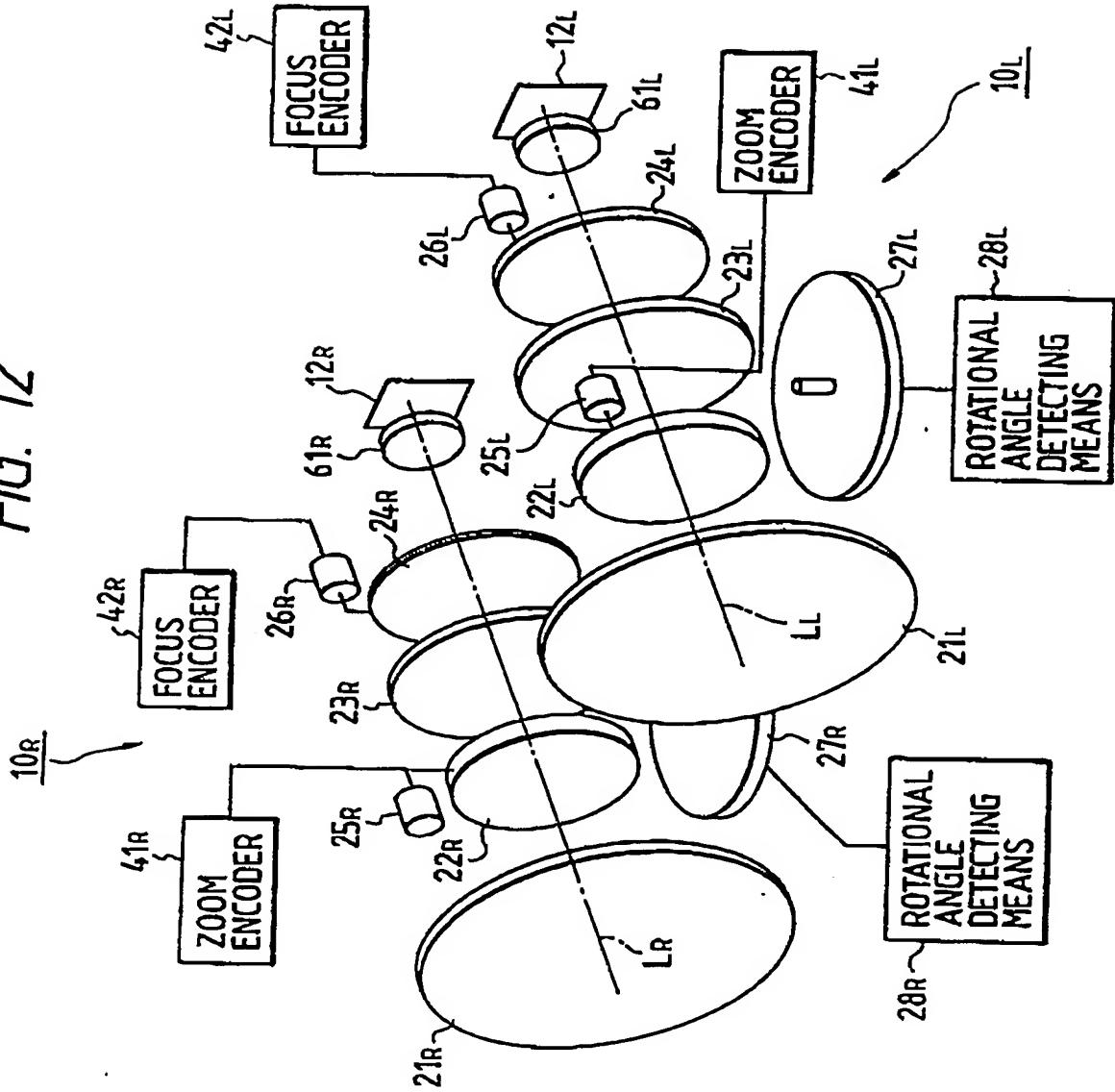
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FIG. 13
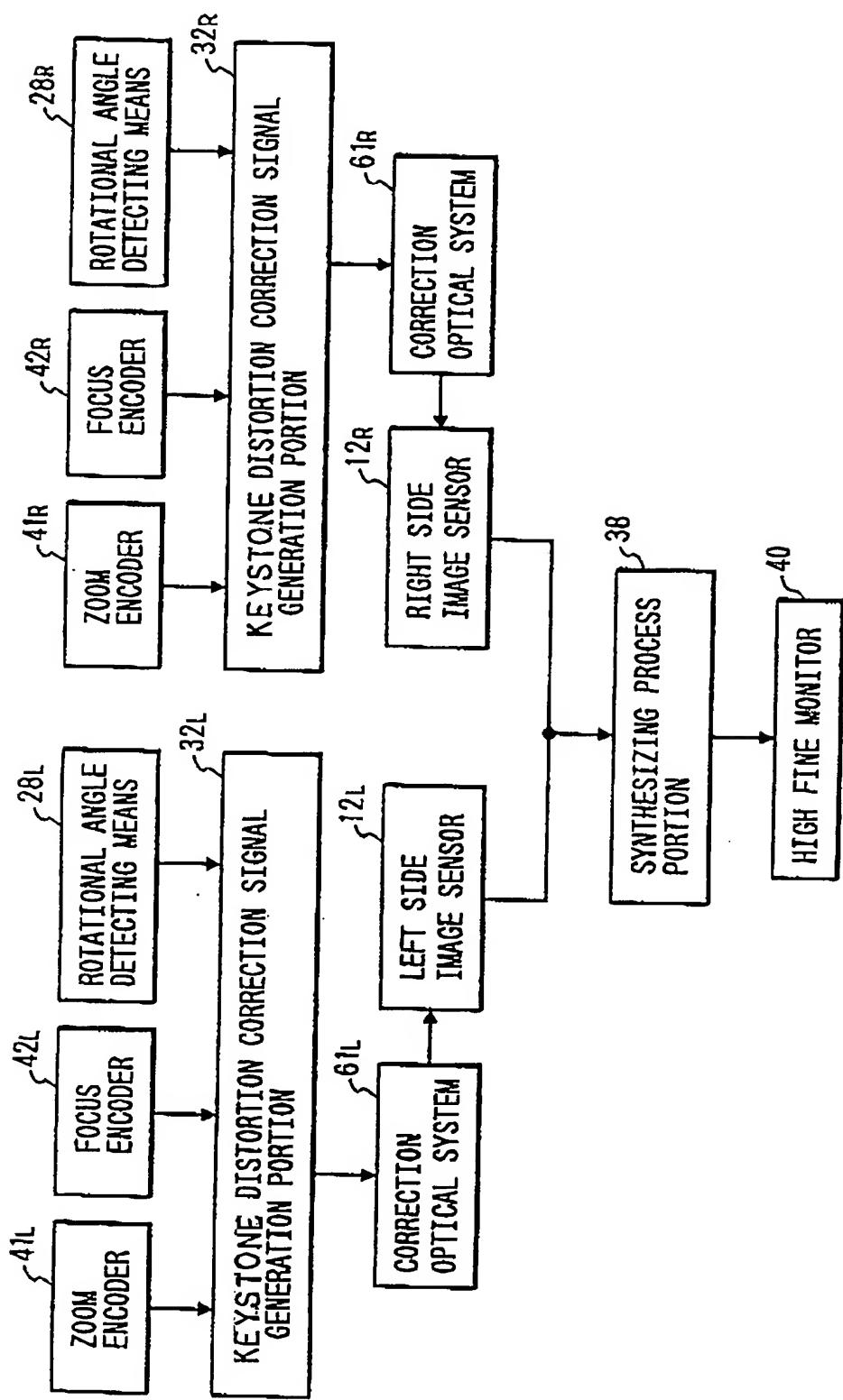
FIG. 14
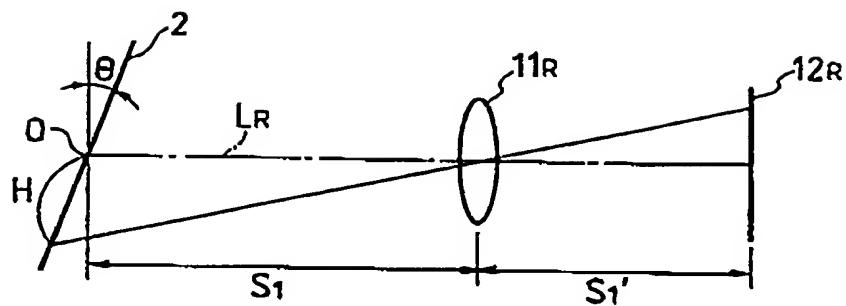
FIG. 15
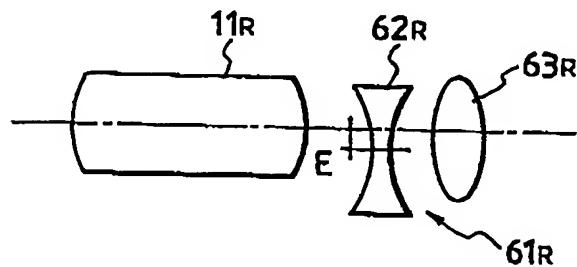
FIG. 16
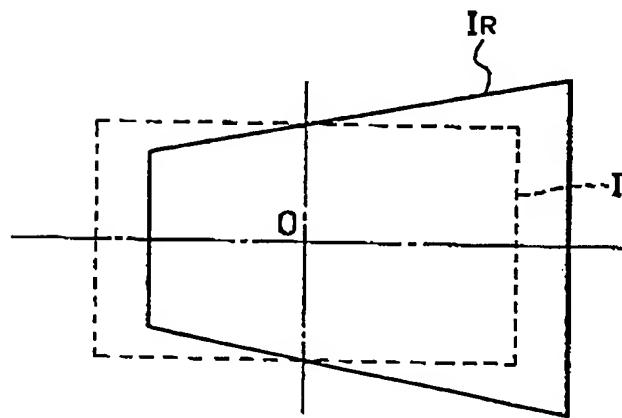
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FIG. 17A
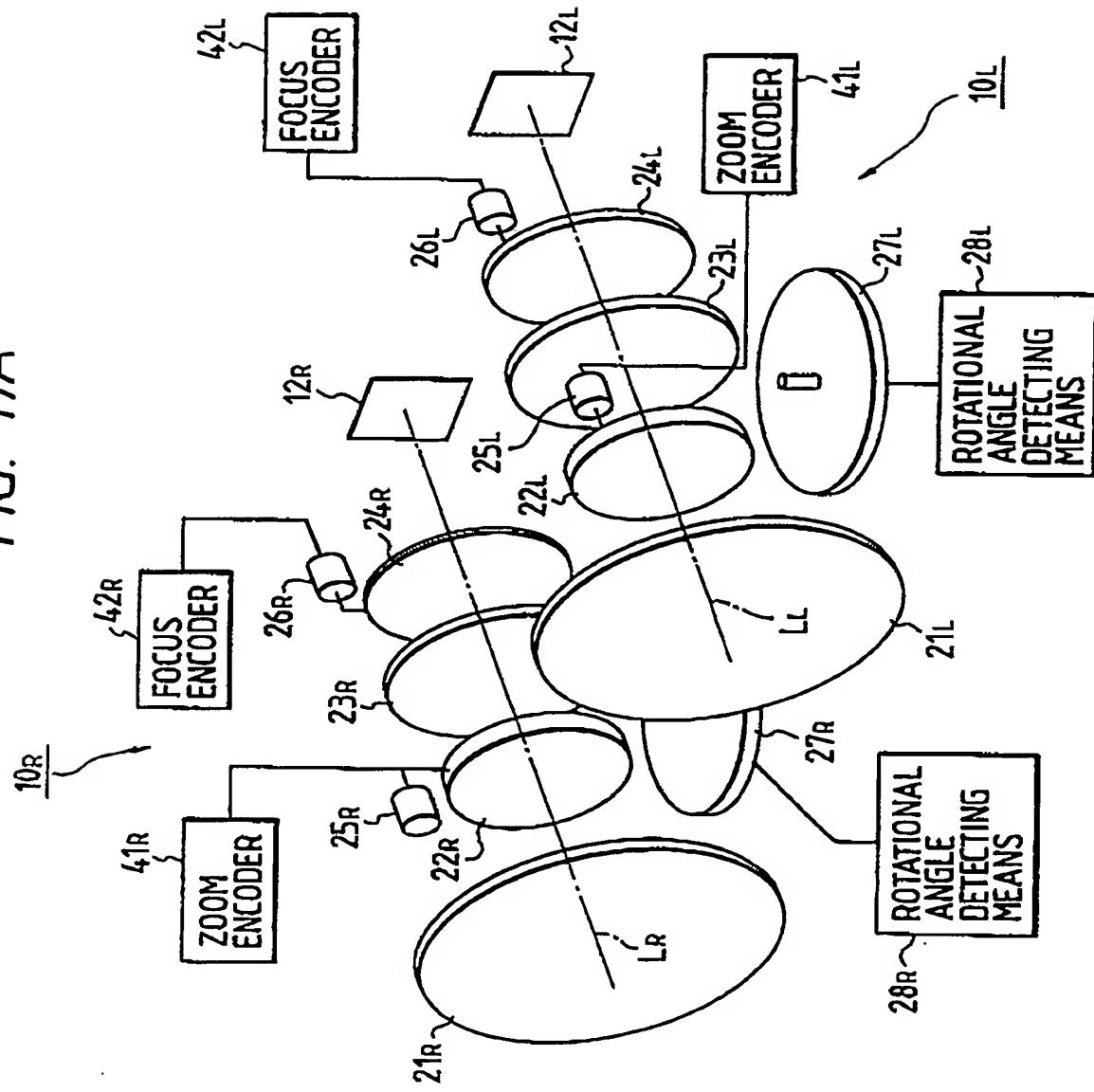
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FIG. 17B
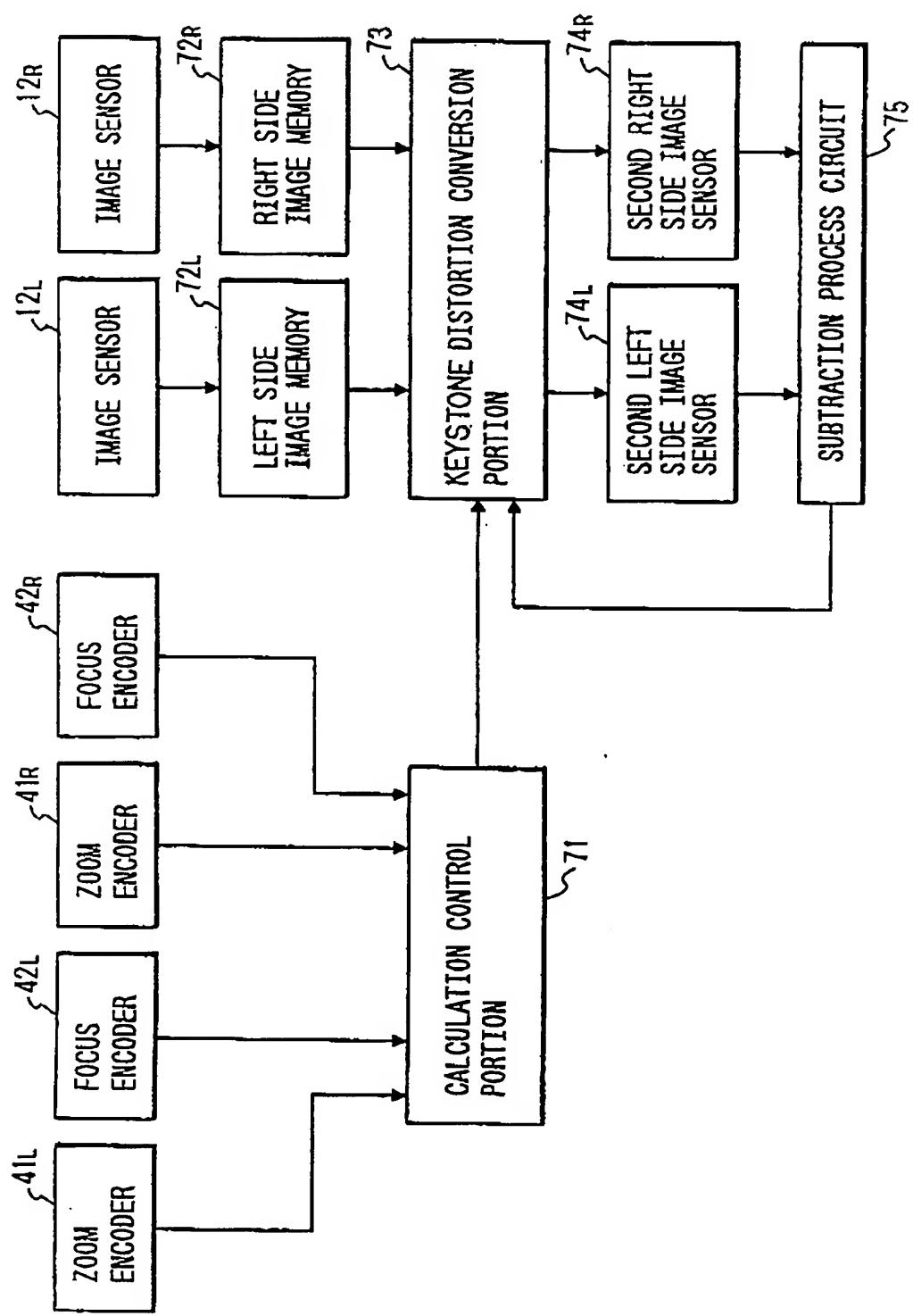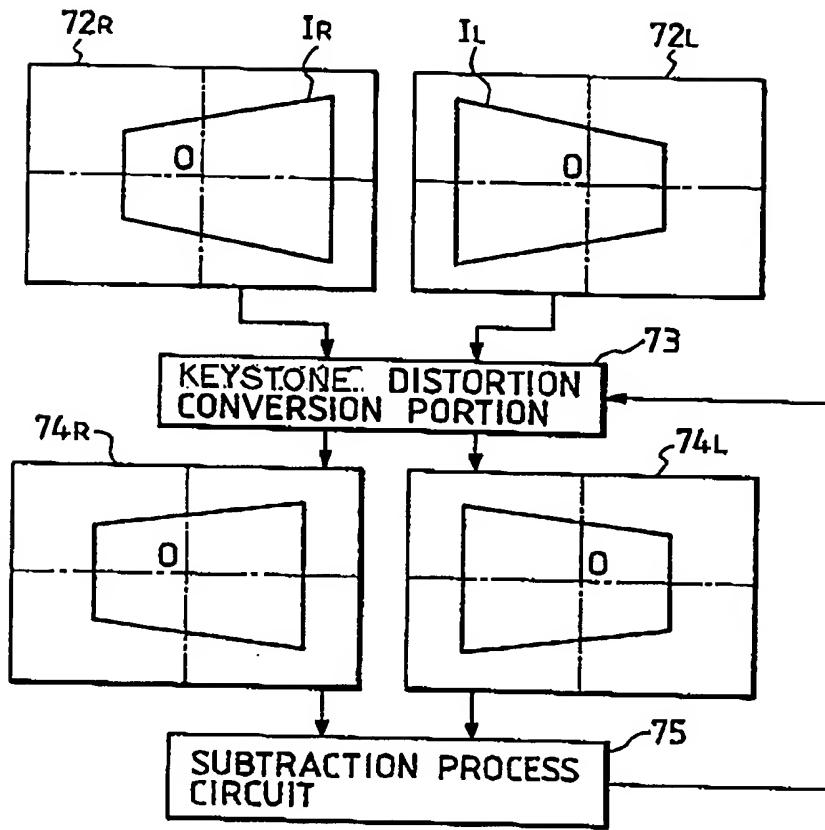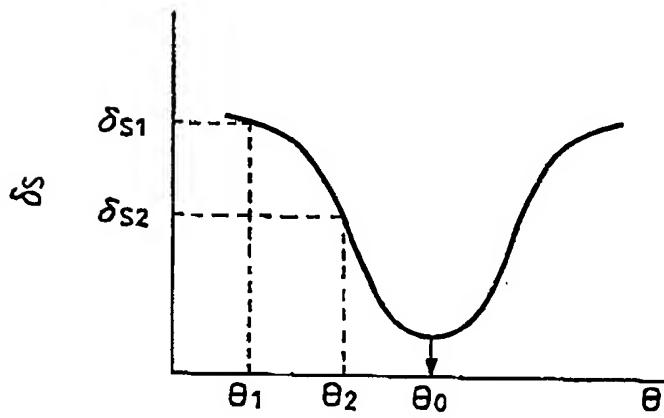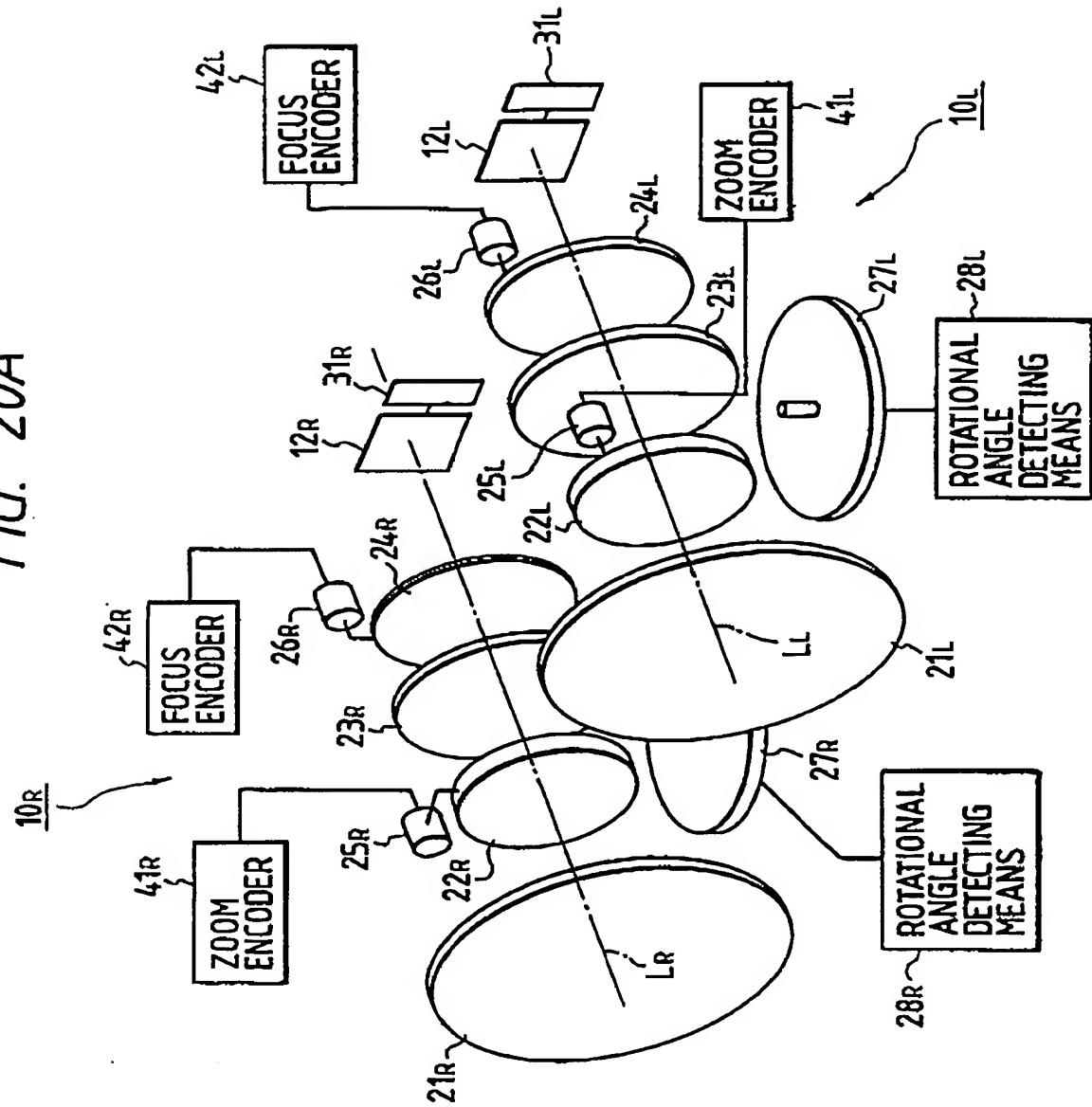
FIG. 18

KEYSTONE DISTORTION CONVERSION PORTION

SUBTRACTION PROCESS CIRCUIT

FIG. 19

45

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FIG. 20A

FIG. 20B

FIG. 21A

48

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FIG. 21C

LEFT PHOTO IMAGE SENSOR — 12L
RIGHT PHOTO IMAGE SENSOR — 12R

LEFT PHOTO IMAGE MEMORY — 232L
RIGHT PHOTO IMAGE MEMORY — 232R

SYNTHESIZING PROCESS CIRCUIT — 233

SYNTHESIZED PHOTO IMAGE SIGNAL

FIG. 21B

MOTOR — 27L
MOTOR — 27R

ROTATIONAL ANGLE DETECTING MEANS — 28L
ROTATIONAL ANGLE DETECTING MEANS — 28R

$\Delta\theta_L$
$\Delta\theta_R$

CONTROL PORTION — 231

$-\Delta\theta_L$
$-\Delta\theta_R$

49
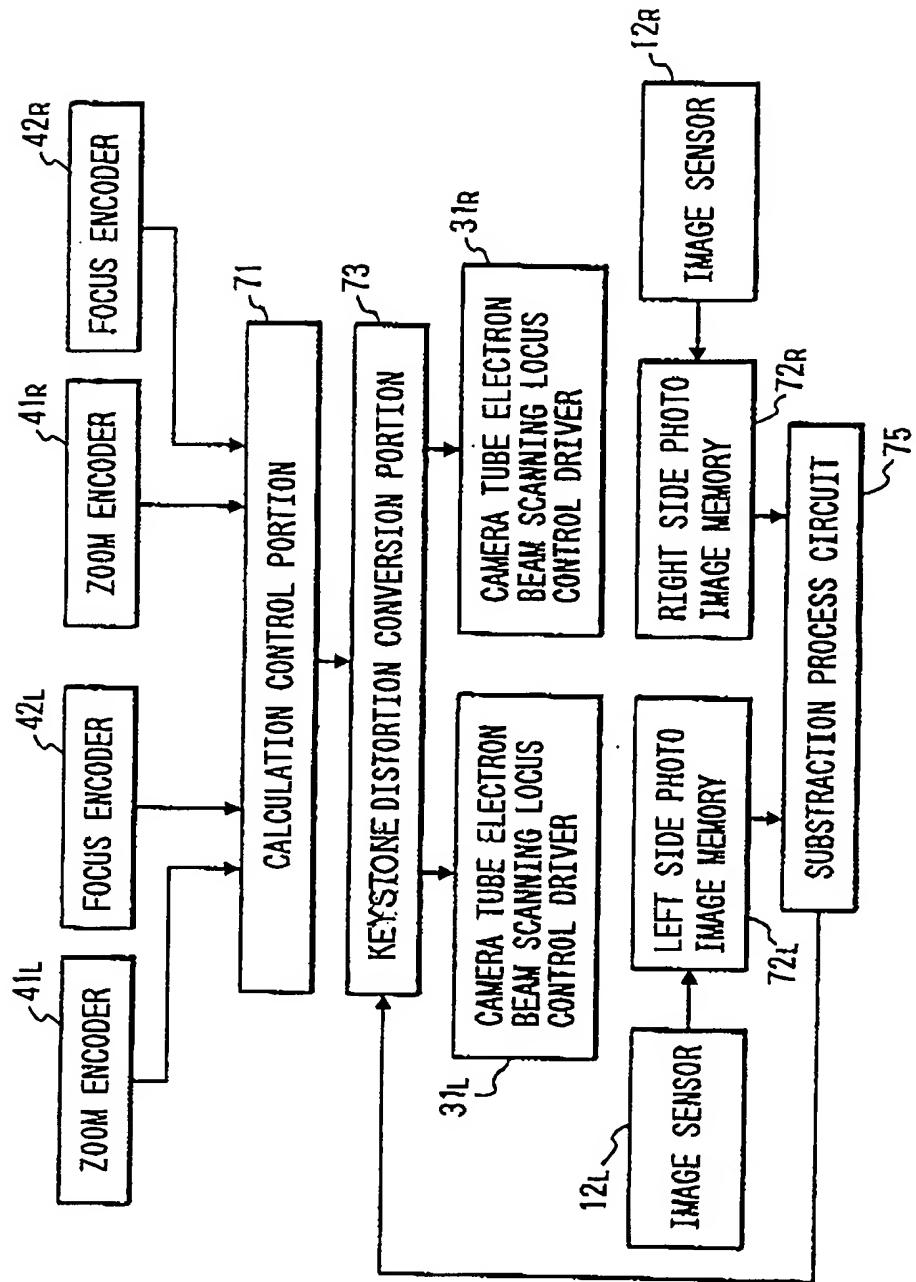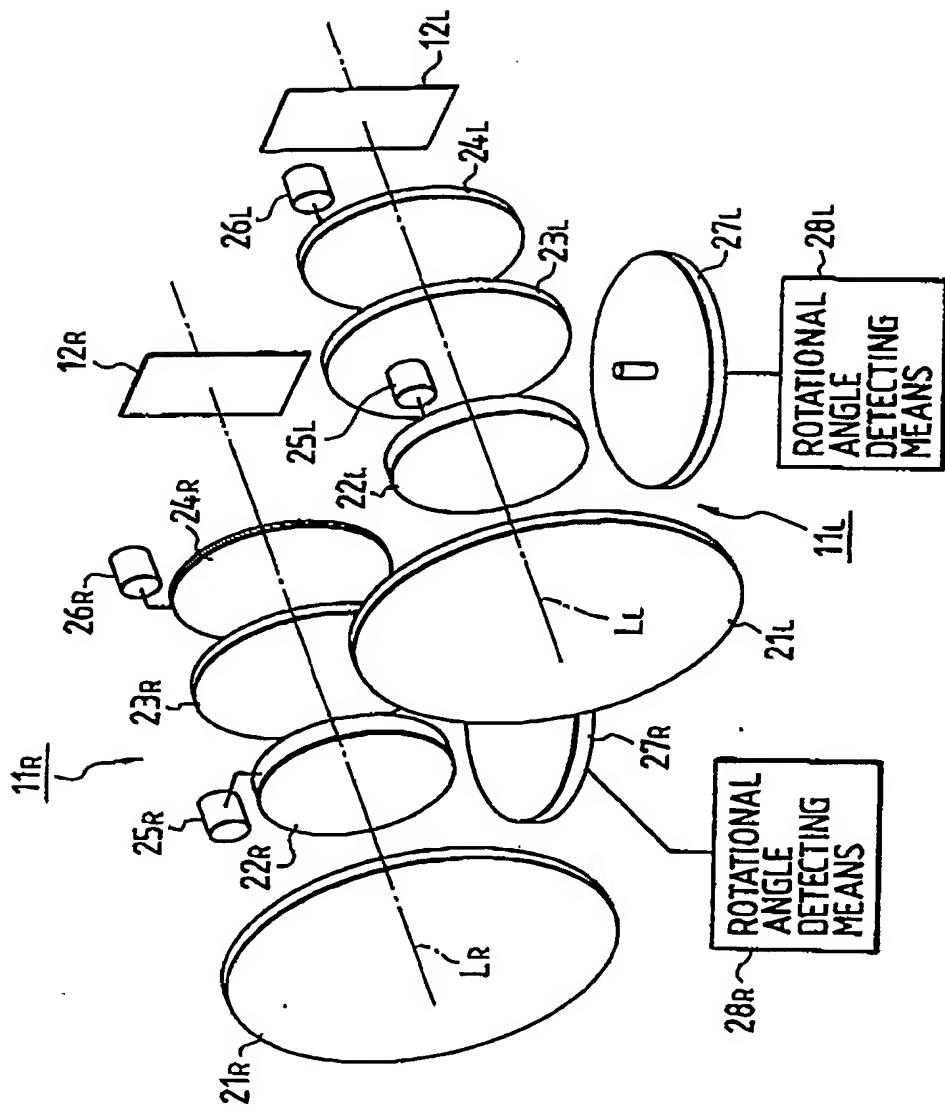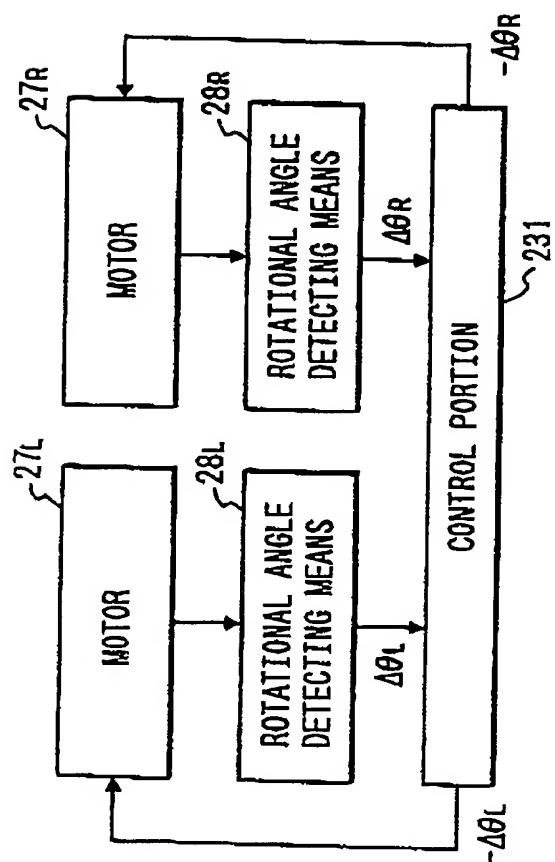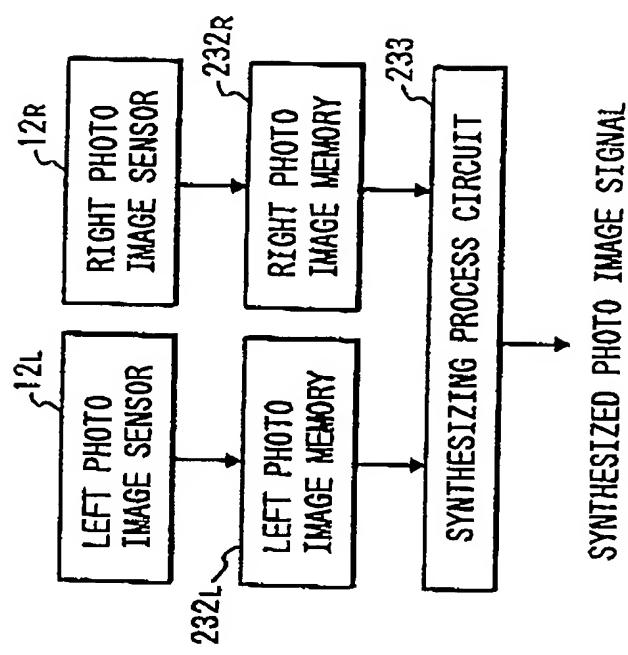
FIG. 22
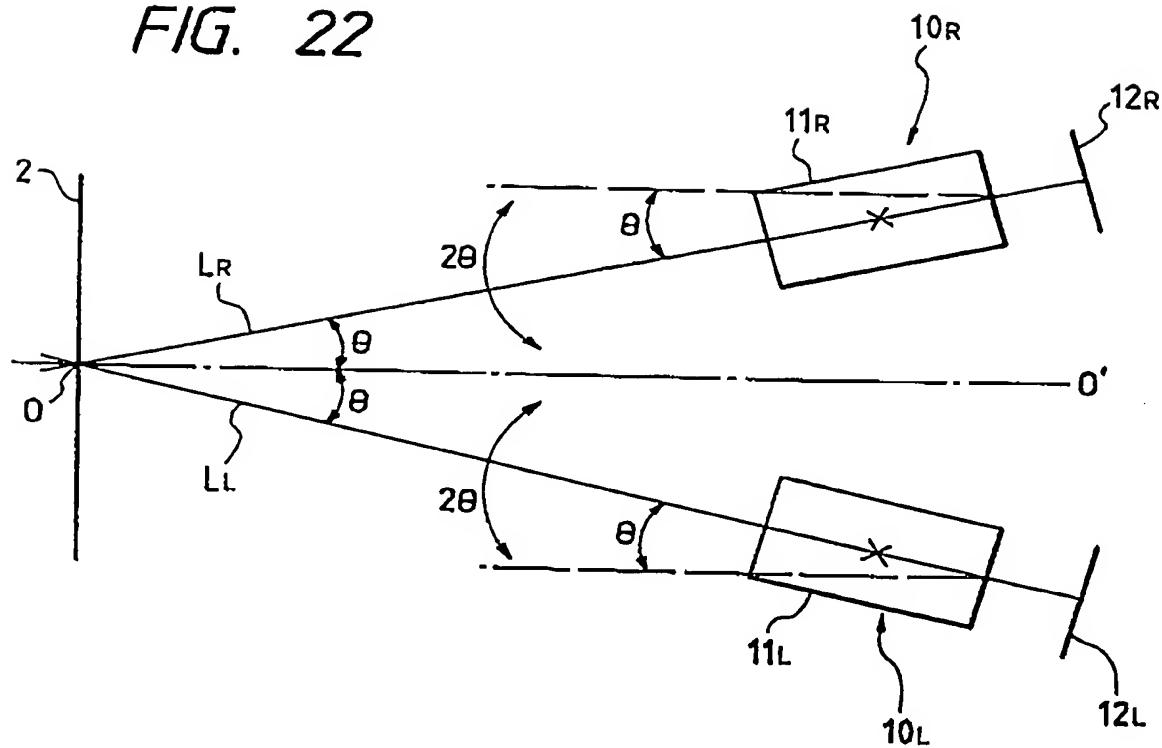
FIG. 23
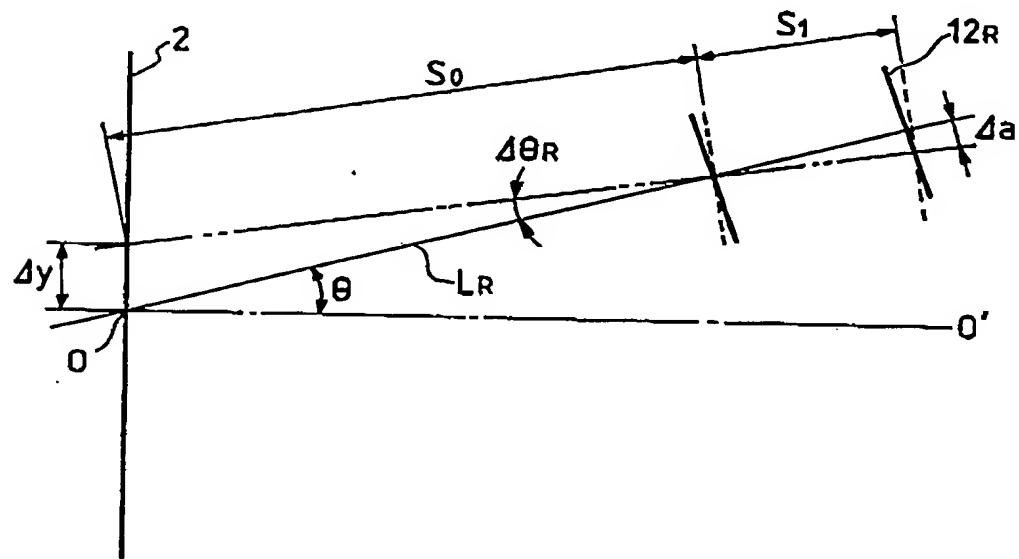
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FIG. 24A
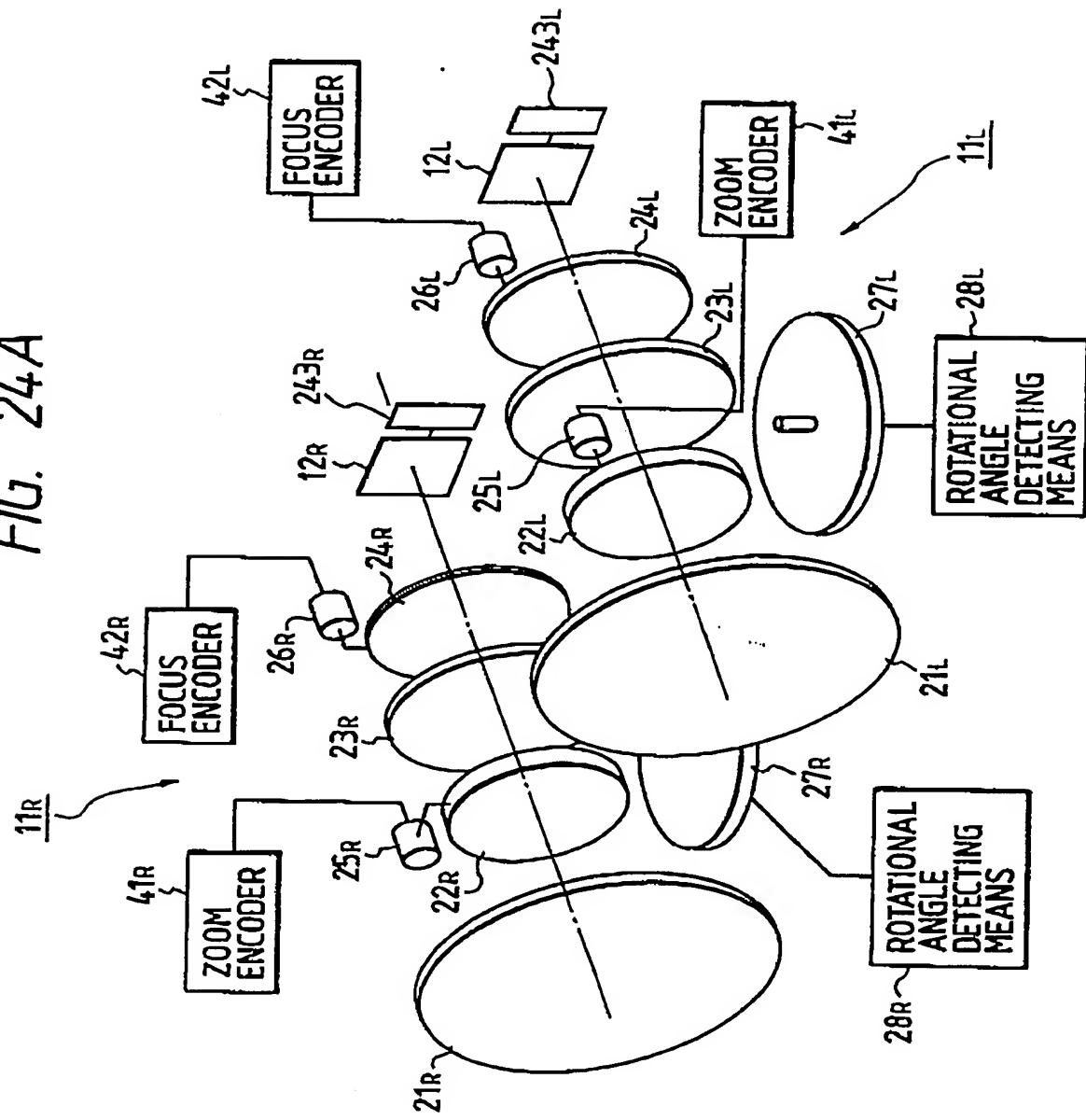
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FIG. 24B
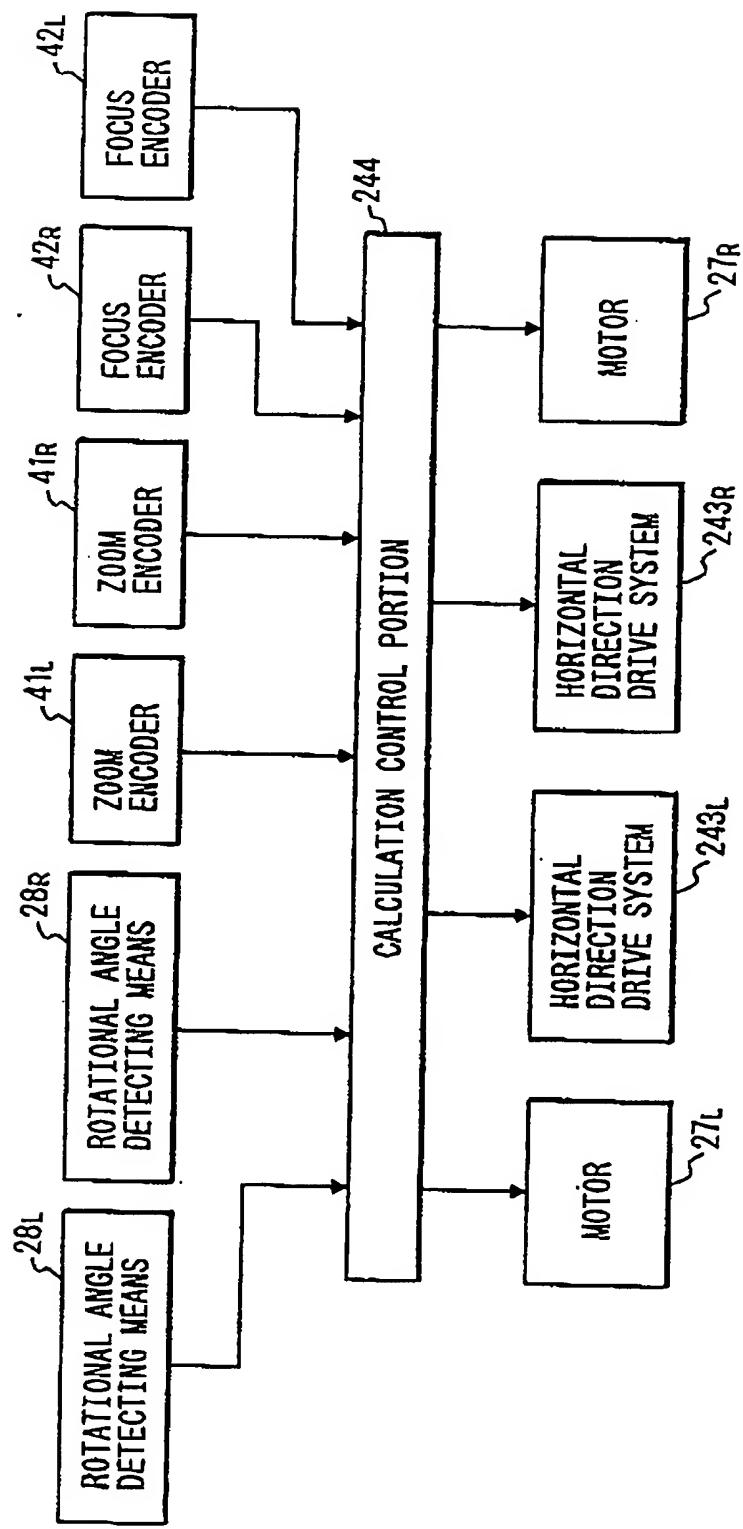
FIG. 25A

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FIG. 25B
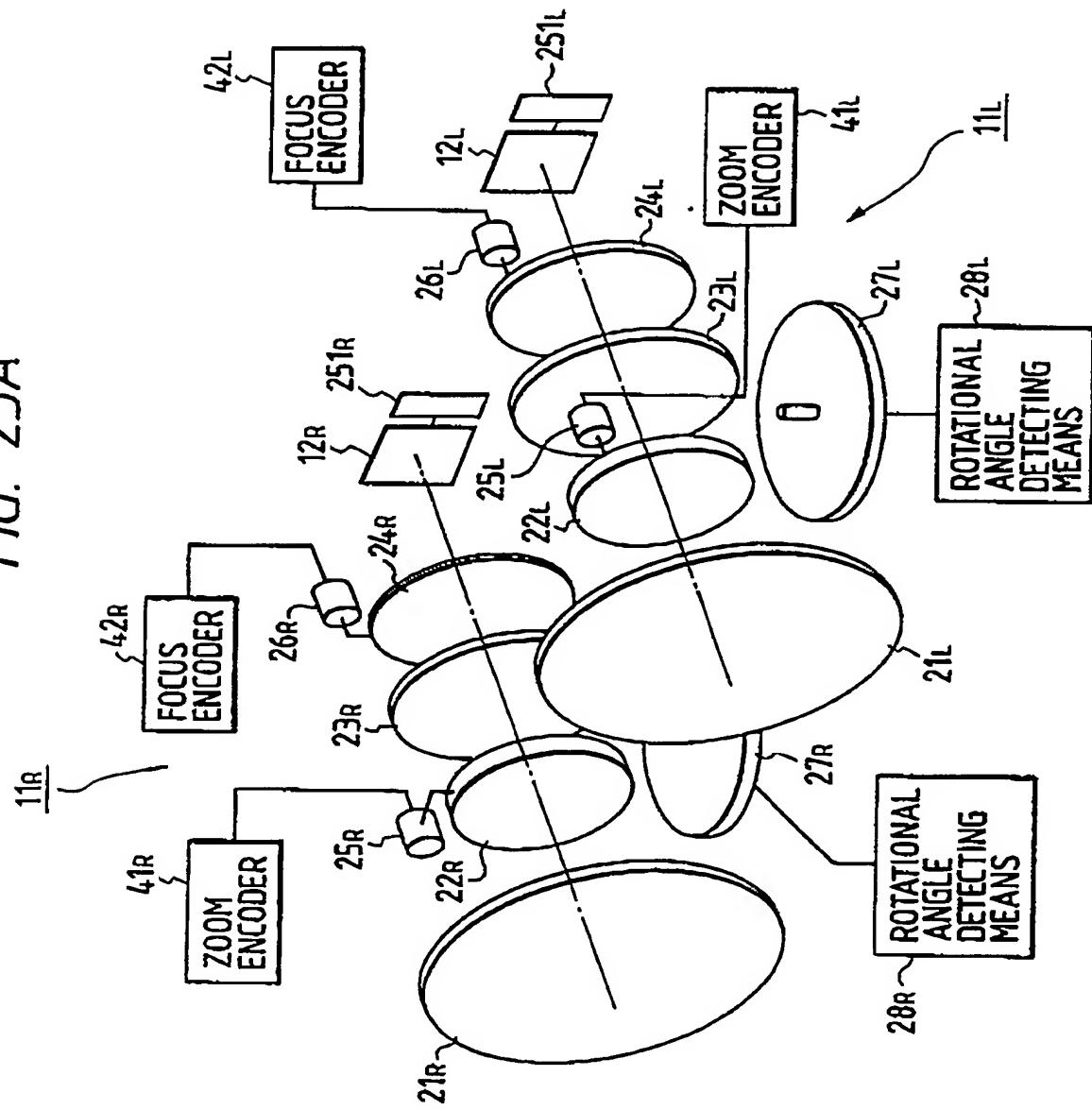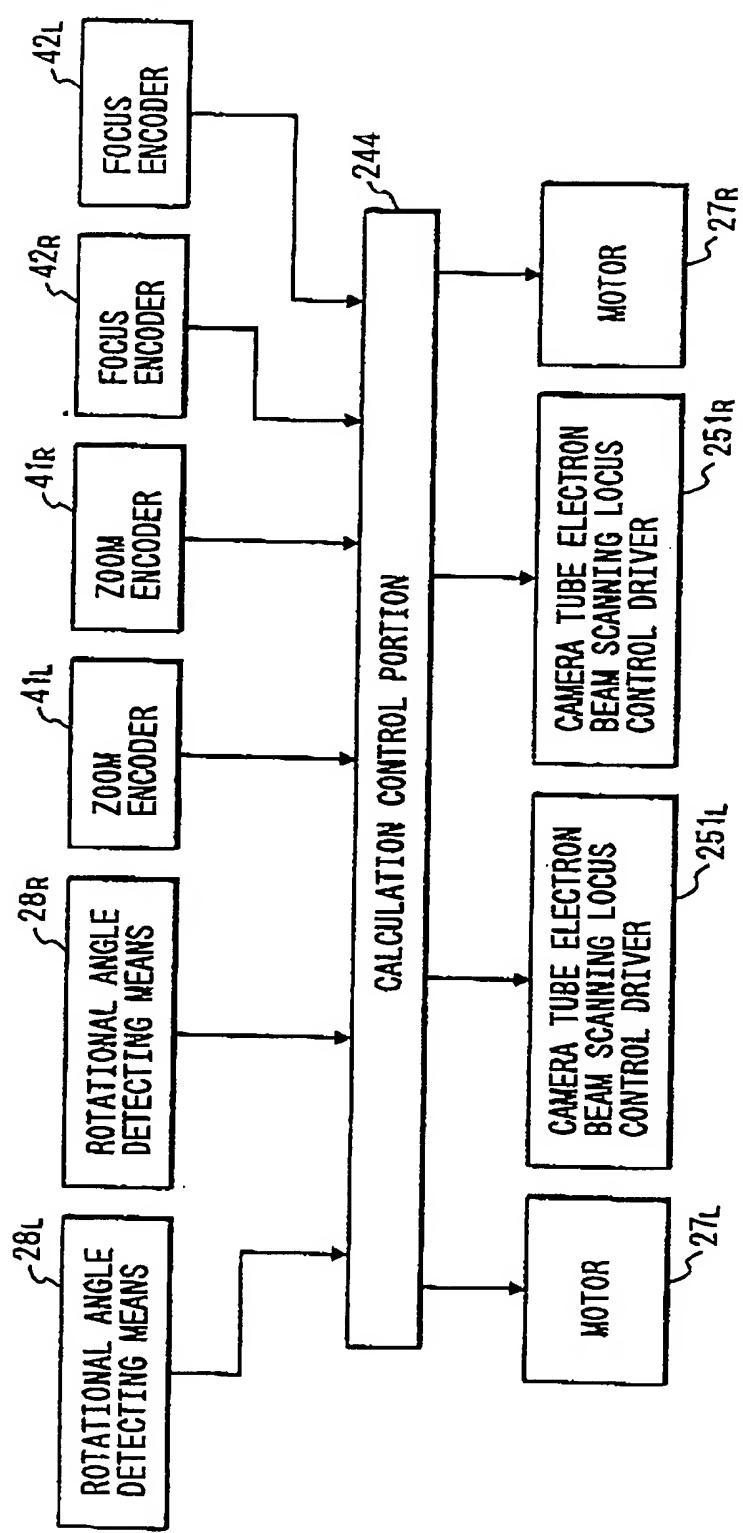
FIG. 26A

FIG. 26B

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FIG. 28

RIGHT SIDE IMAGE SENSOR `12R` → RIGHT SIDE IMAGE MEMORY `232R`

LEFT SIDE IMAGE SENSOR `12L` → LEFT SIDE IMAGE MEMORY `232L` → CALCULATION PROCESS PORTION `282` → THIRD LEFT SIDE IMAGE MEMORY `283` → MAGNIFICATION CORELATION CALCULATION PROCESS PORTION `281` → CORRECTION SIGNAL

k

FIG. 27

RIGHT SIDE IMAGE SENSOR `12R` → RIGHT SIDE IMAGE MEMORY `232R`

LEFT SIDE IMAGE SENSOR `12L` → LEFT SIDE IMAGE MEMORY `232L` → CORRECTION CONVERSION PORTION `261` → SECOND LEFT SIDE IMAGE MEMORY `262` → CORELATION CALCULATION PROCESS PORTION `271` → CORRECTION SIGNAL

x

57

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FIG. 29

FIG. 30
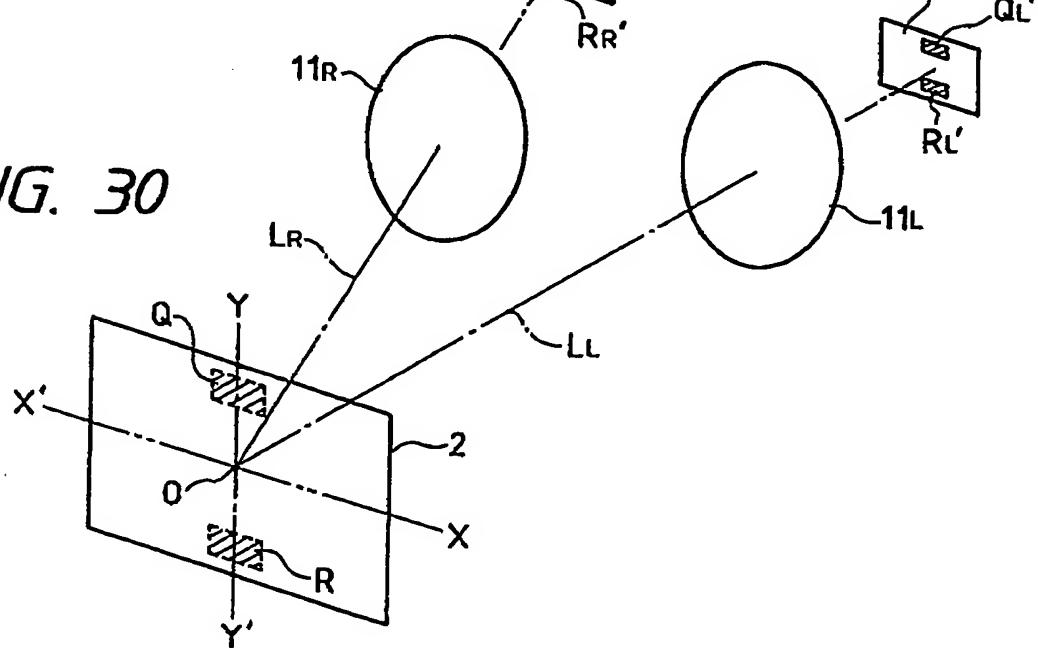
FIG. 31
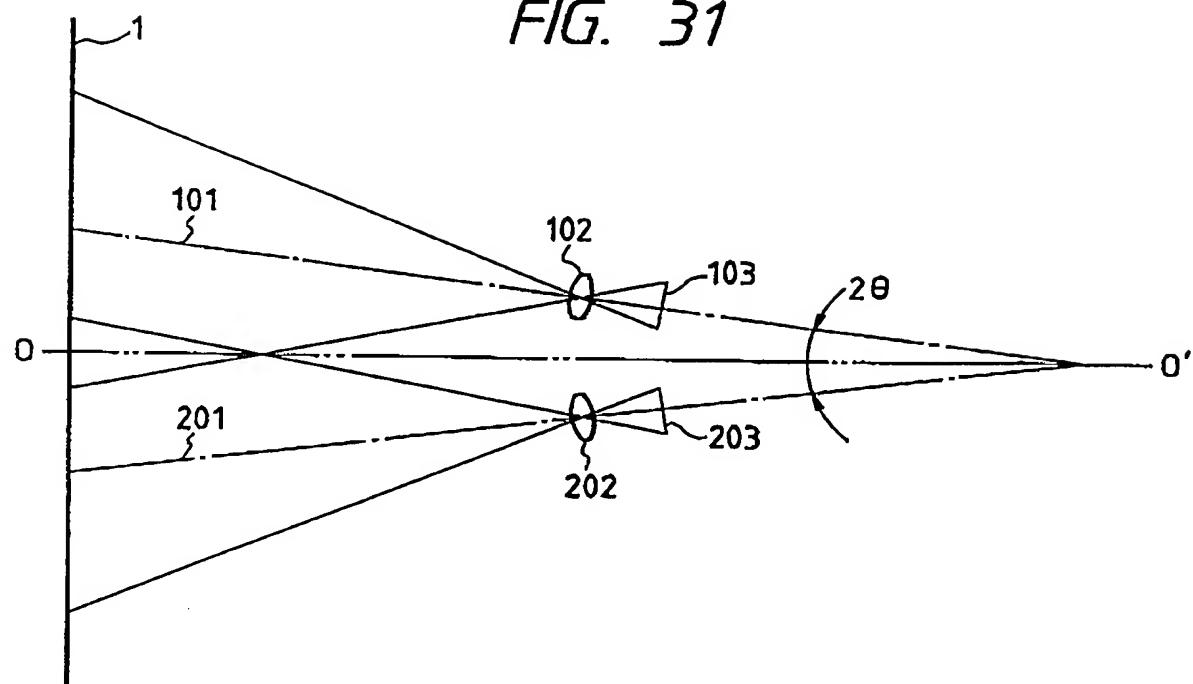
FIG. 32
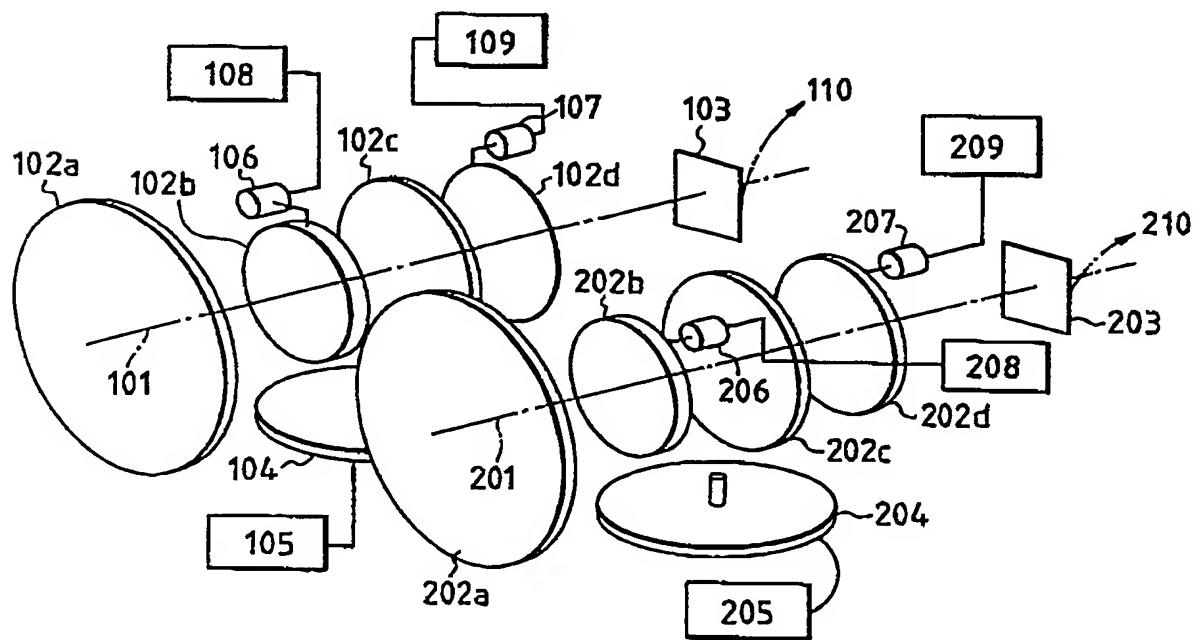
FIG. 33
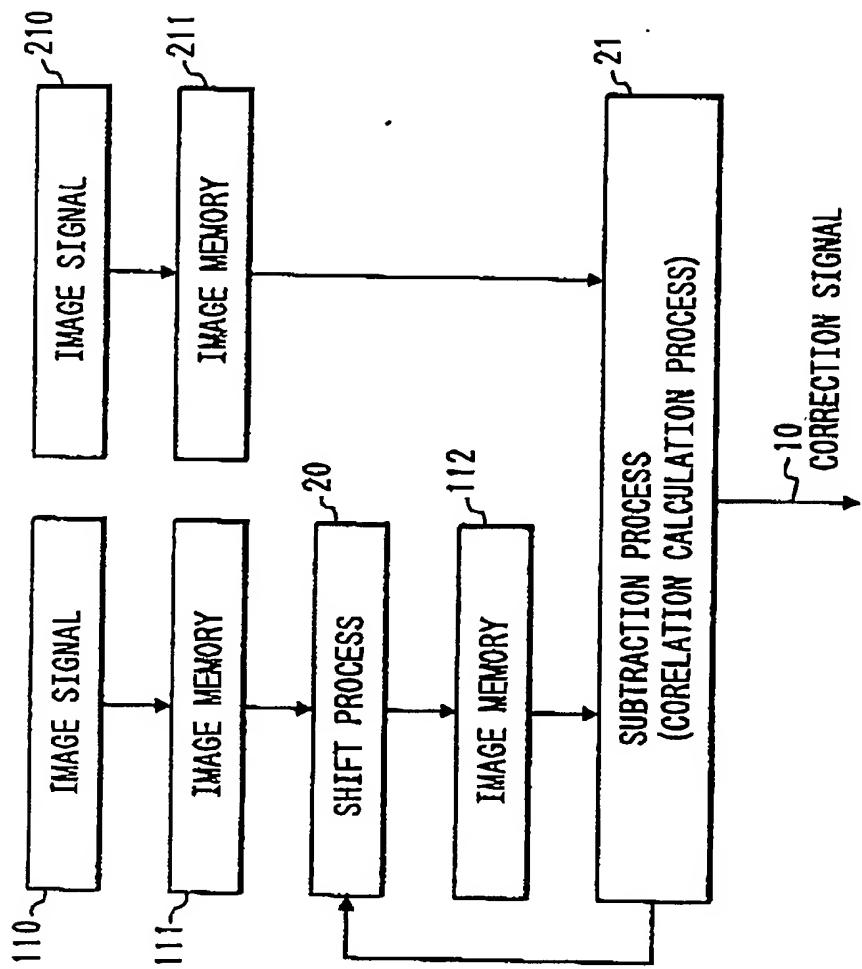
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FIG. 34
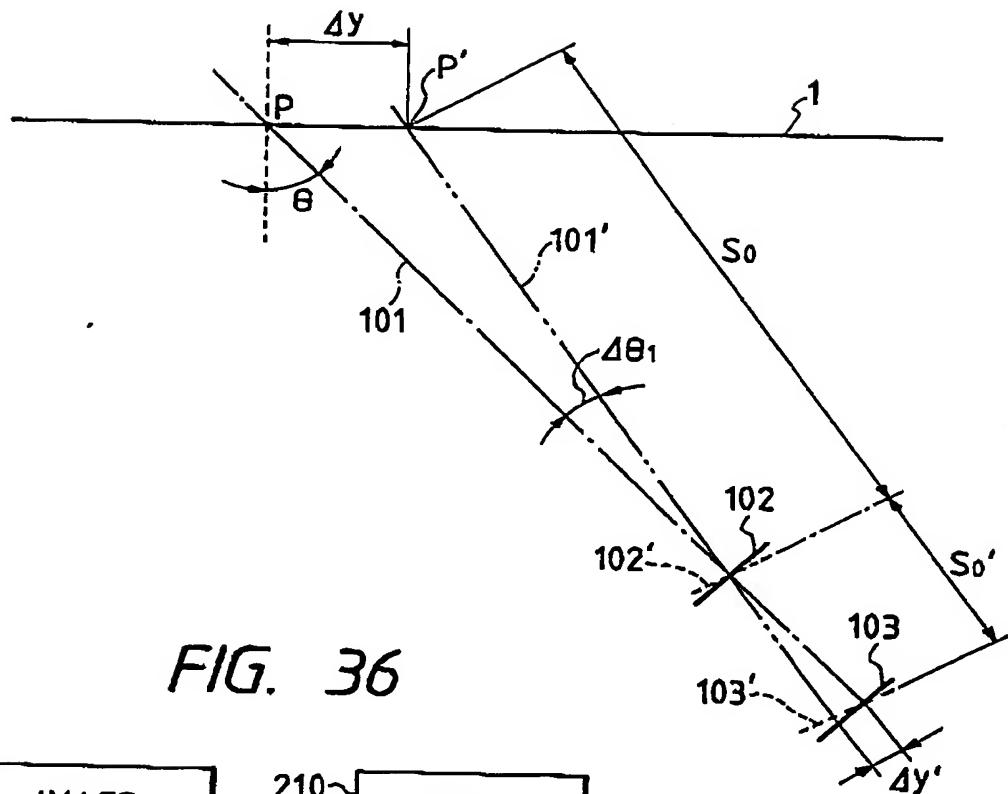
FIG. 36
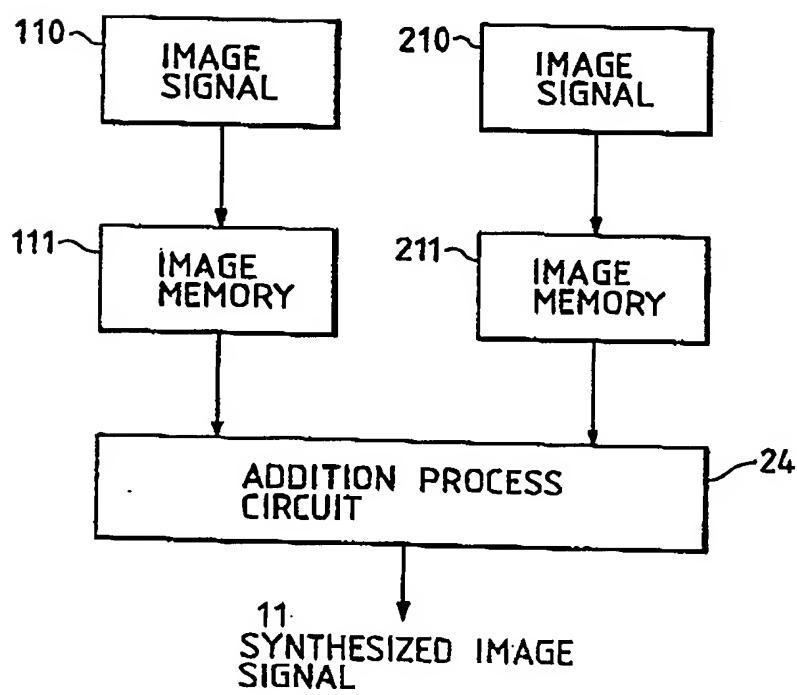
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FIG. 35
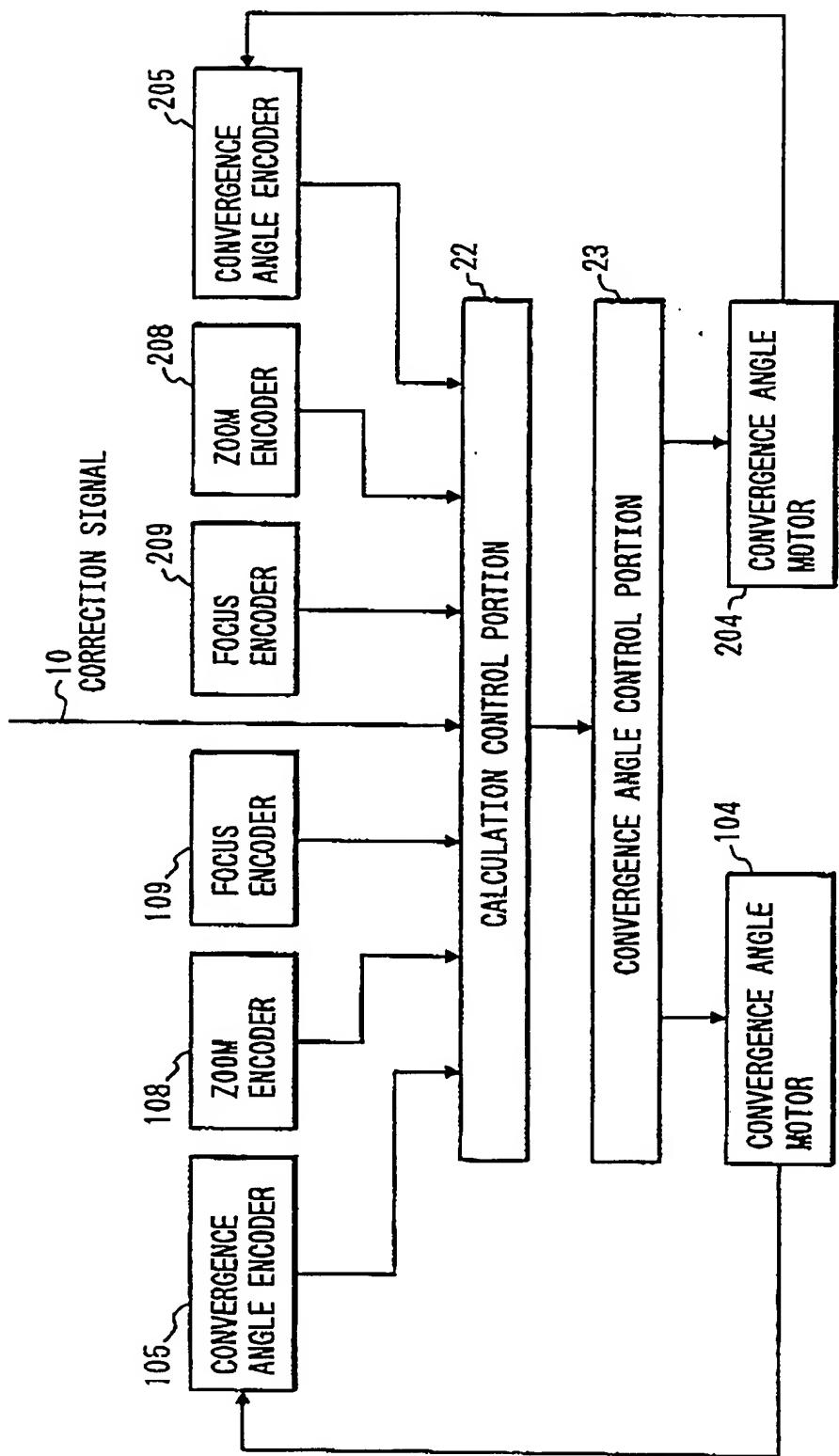
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FIG. 37
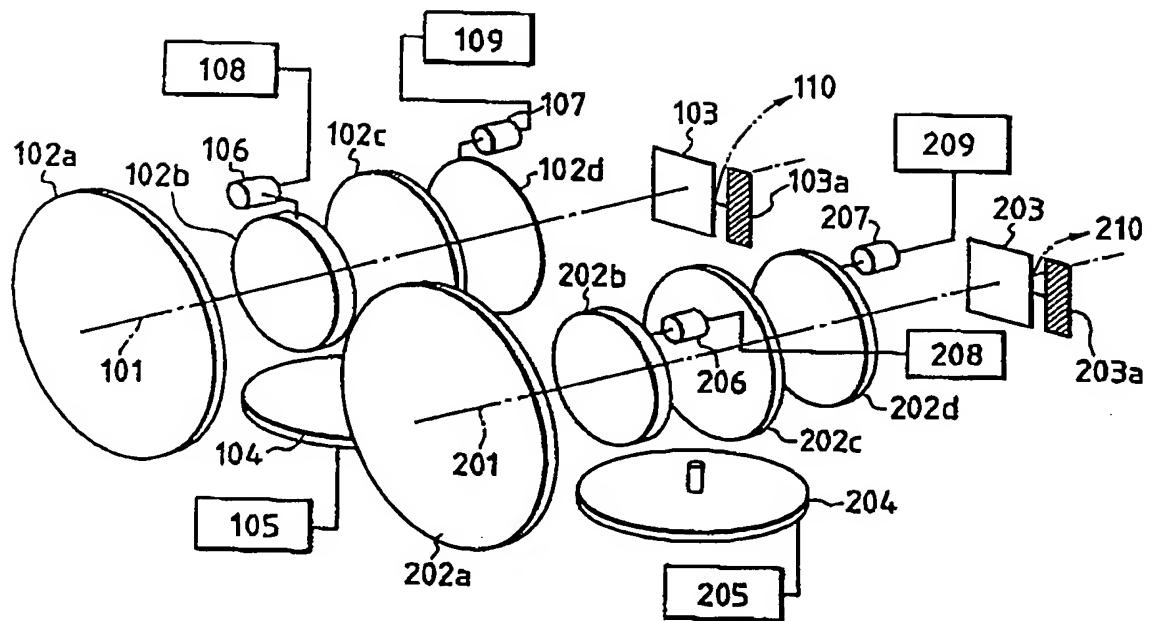
FIG. 39
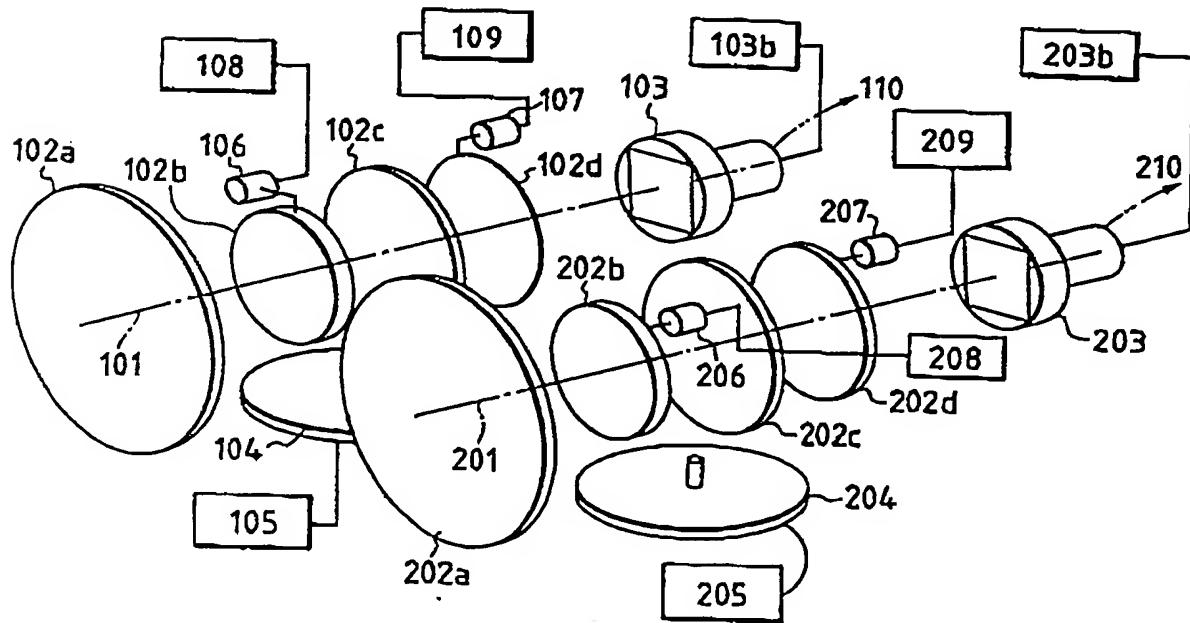
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FIG. 38
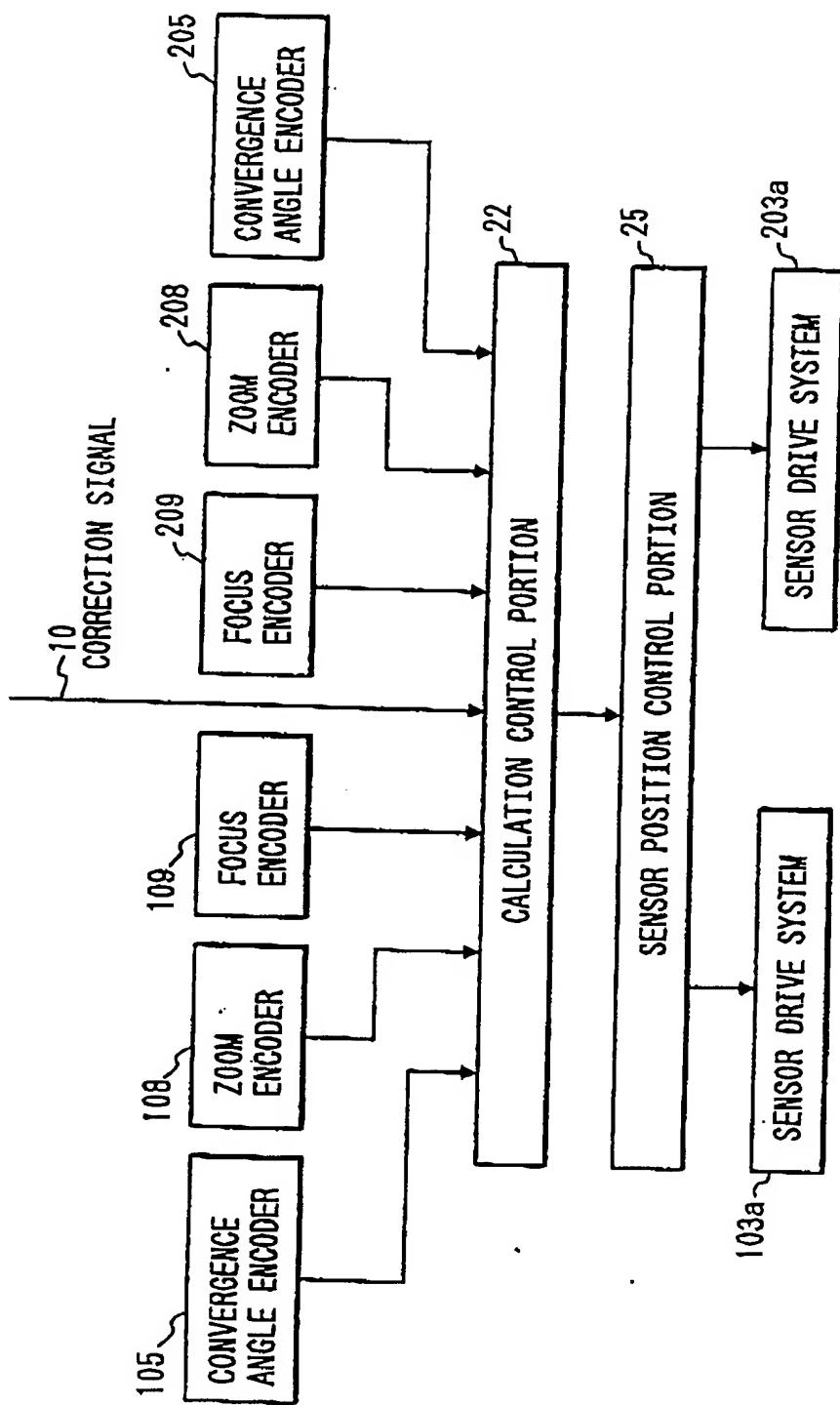
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FIG. 40
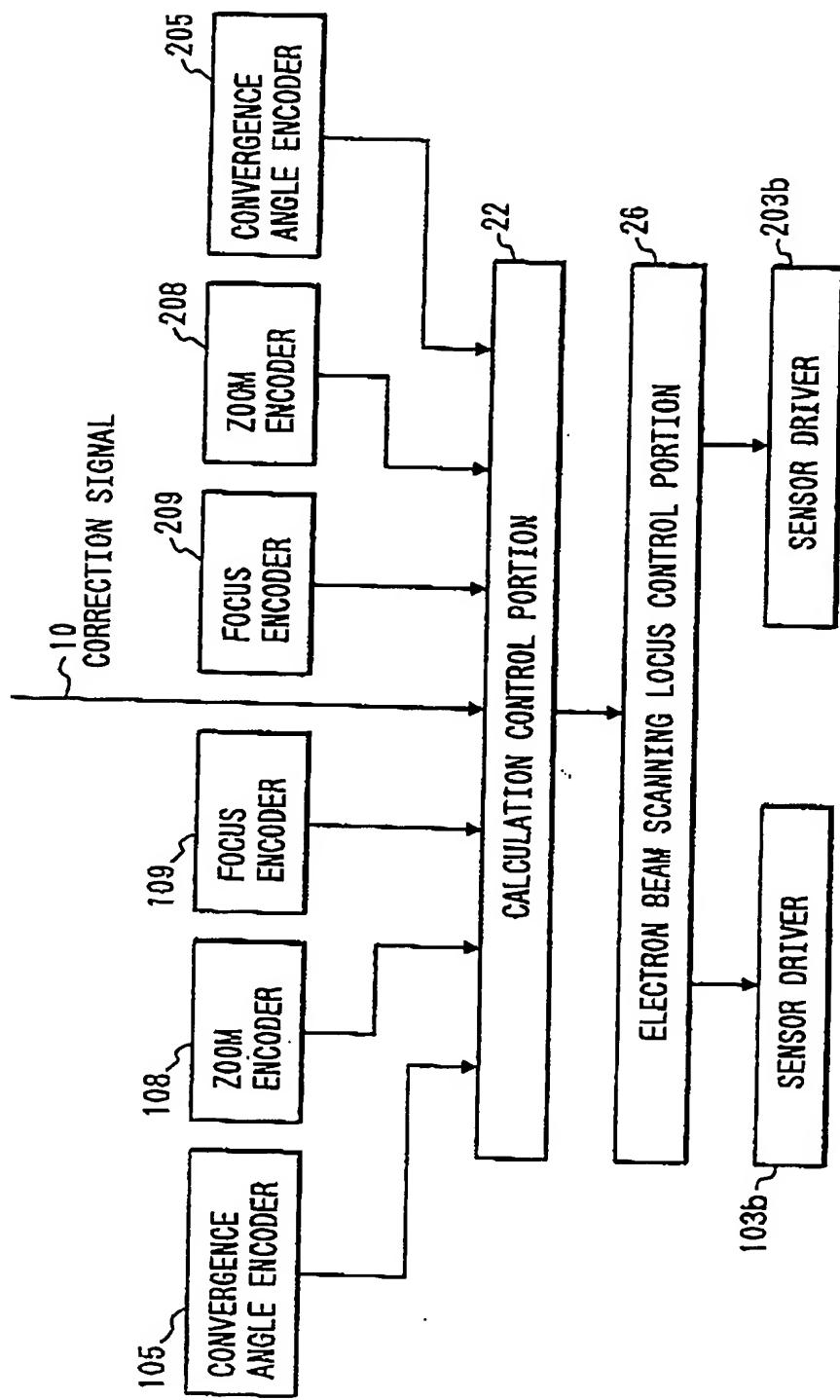
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FIG. 41
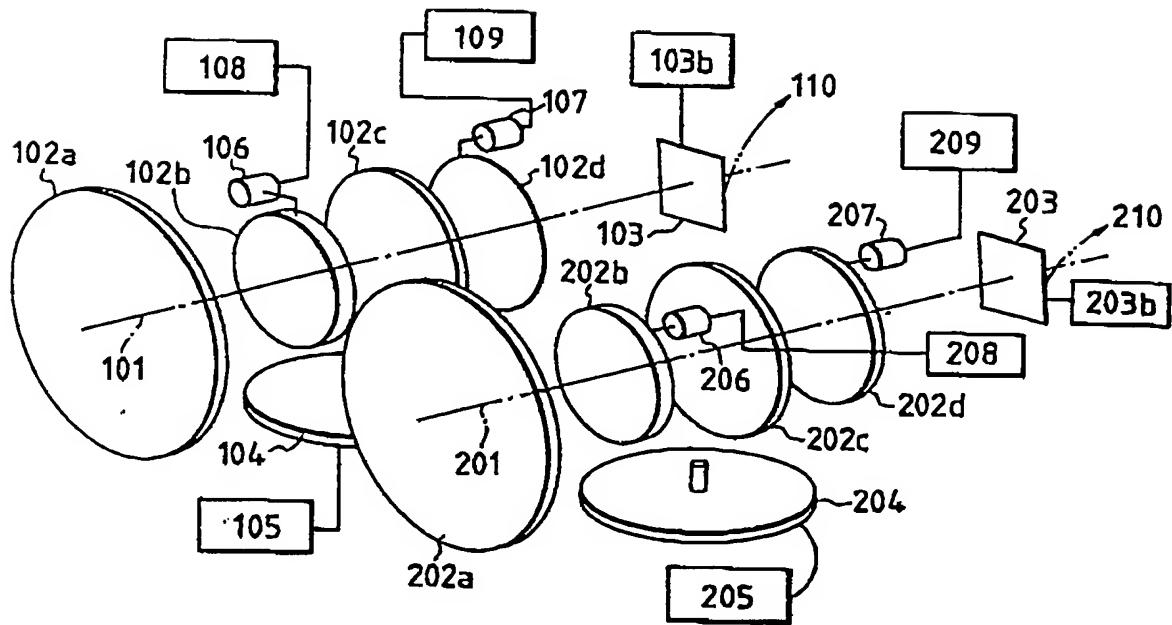
FIG. 43
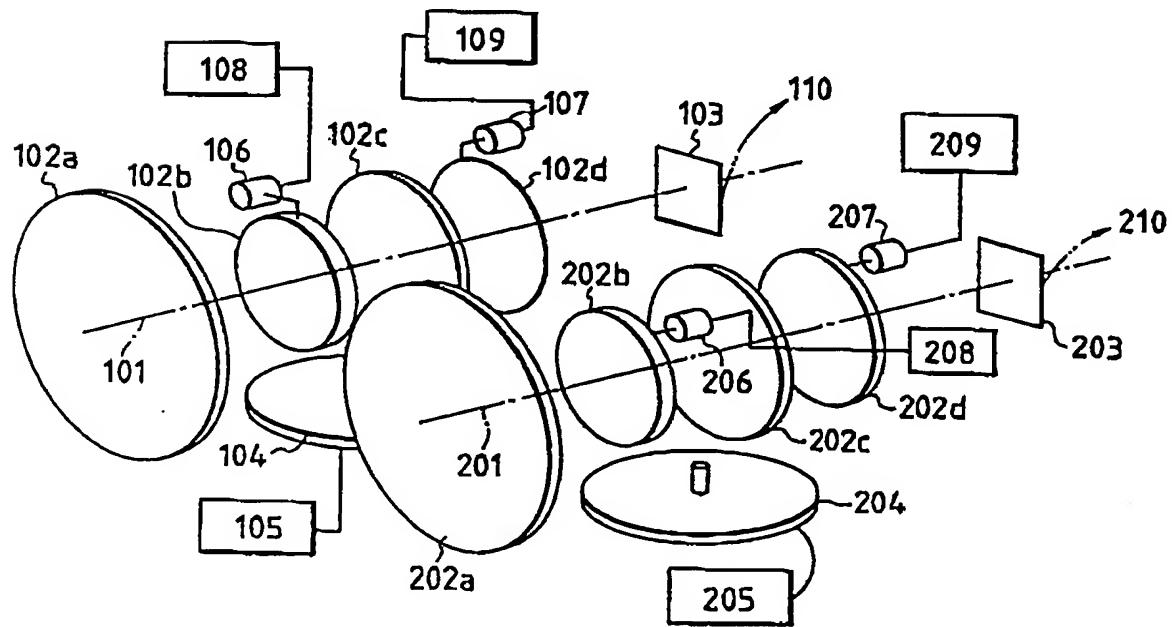
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FIG. 42
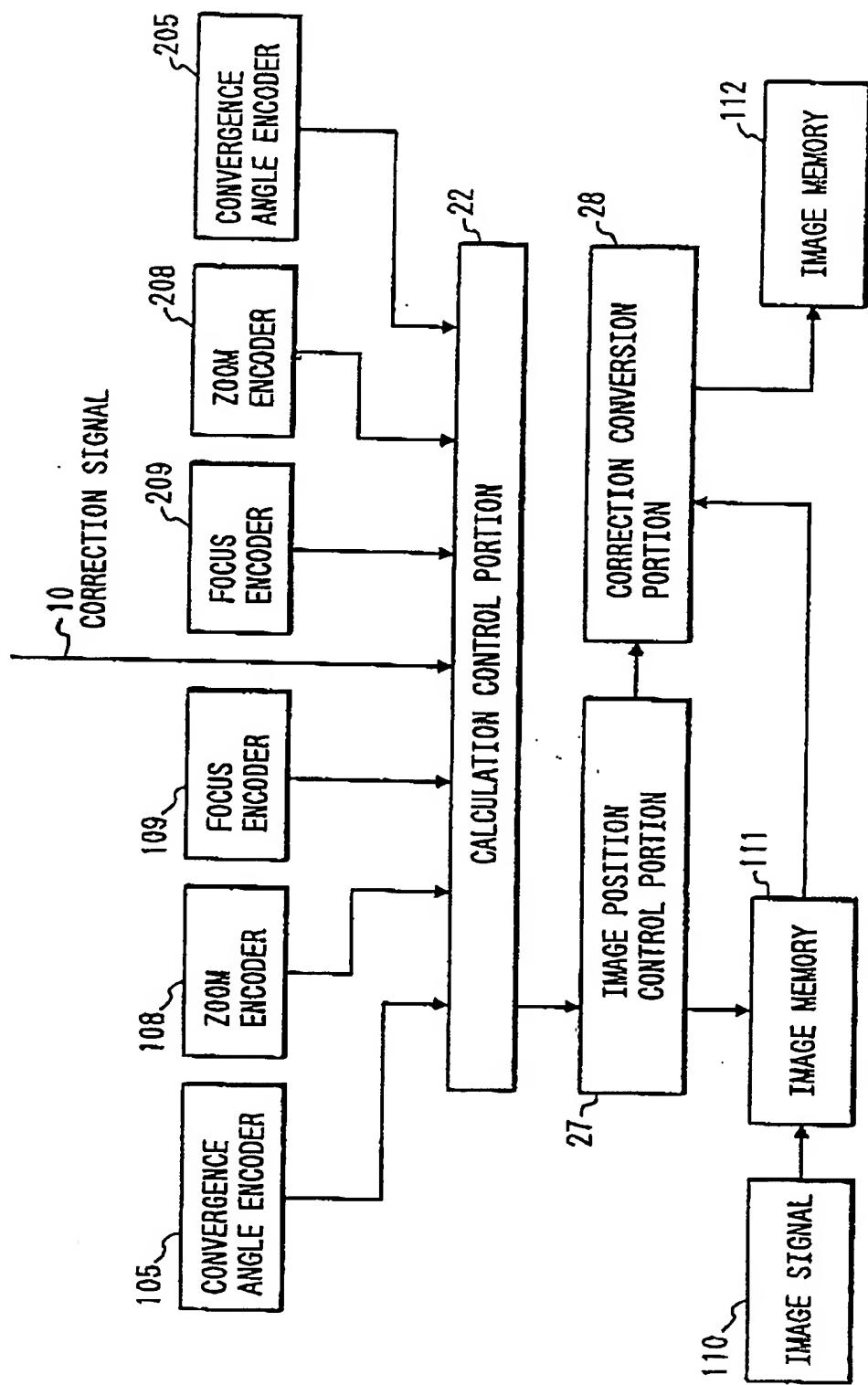
FIG. 44
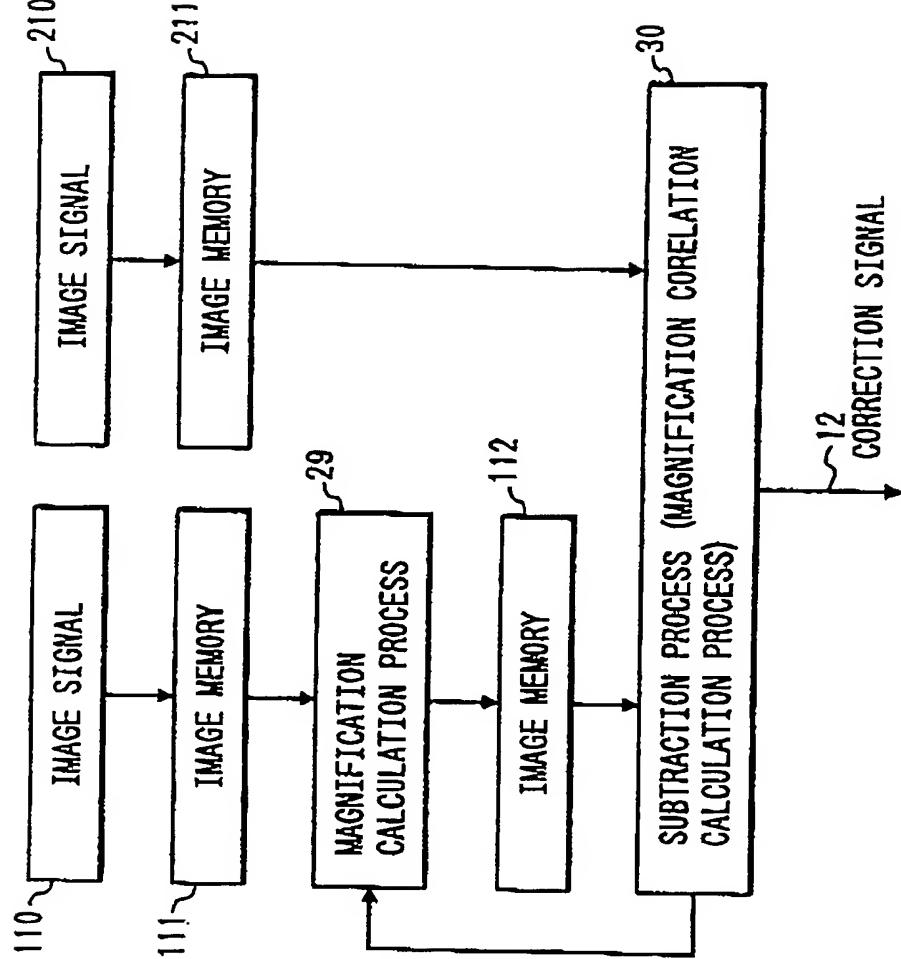
FIG. 45
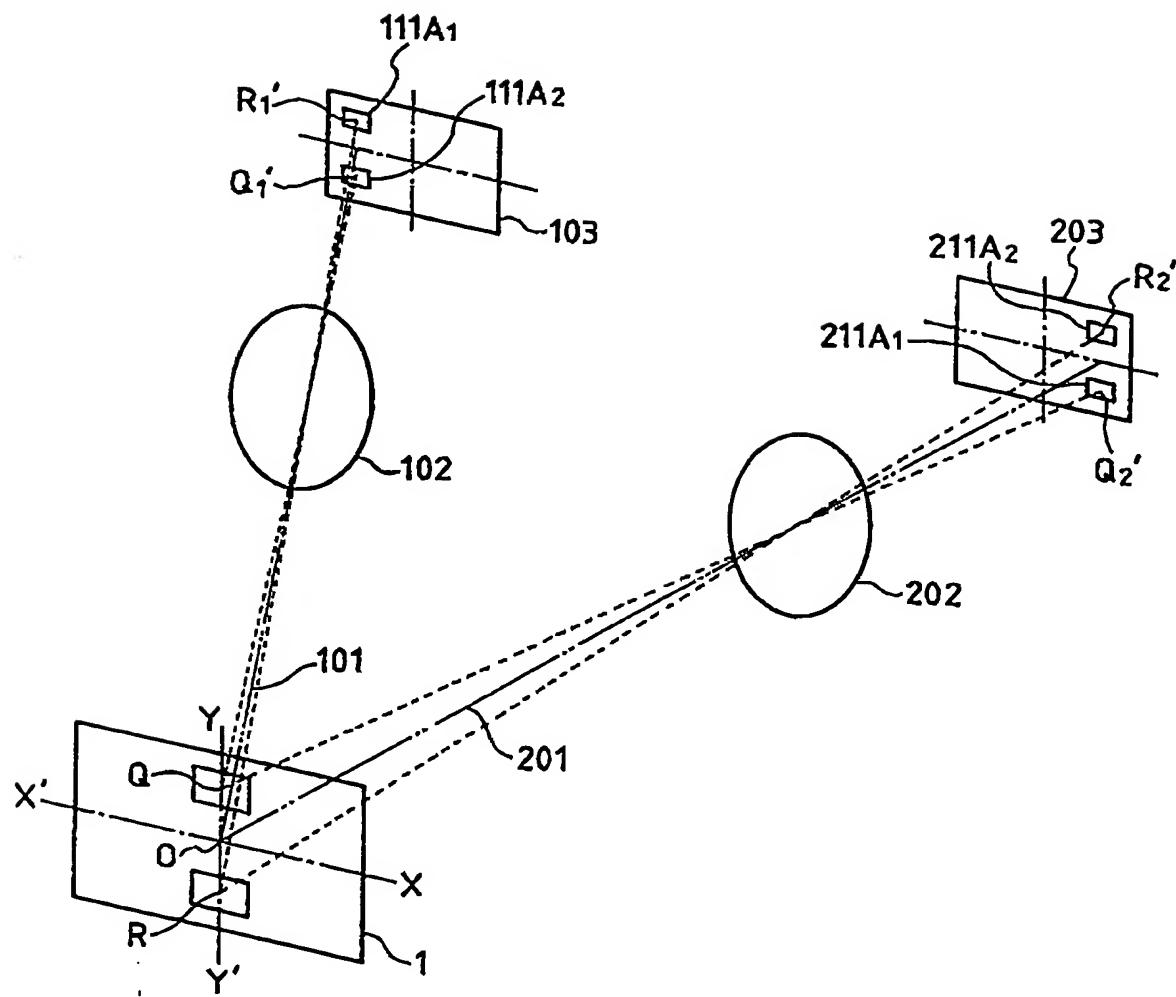
FIG. 46
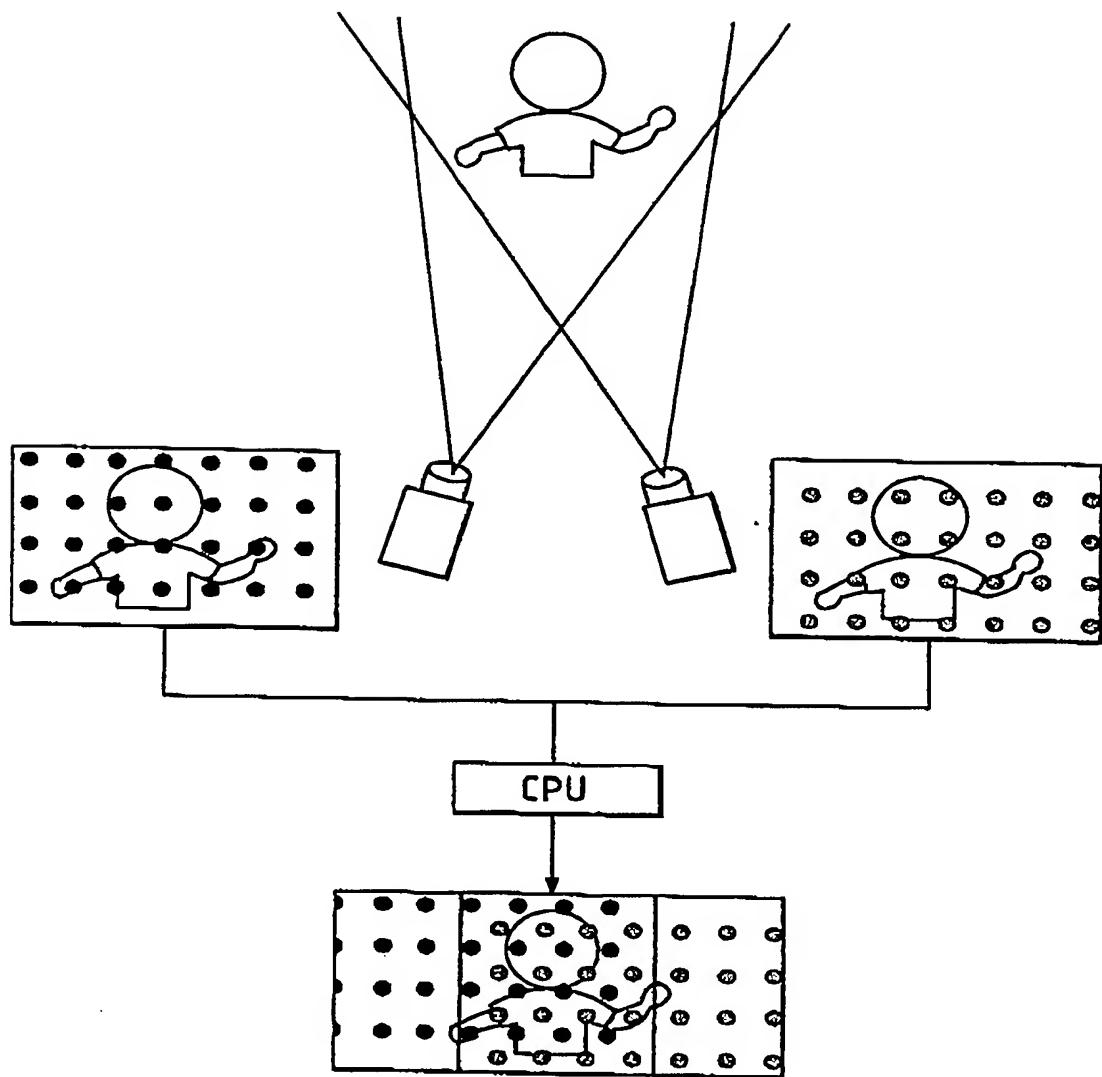
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FIG. 47
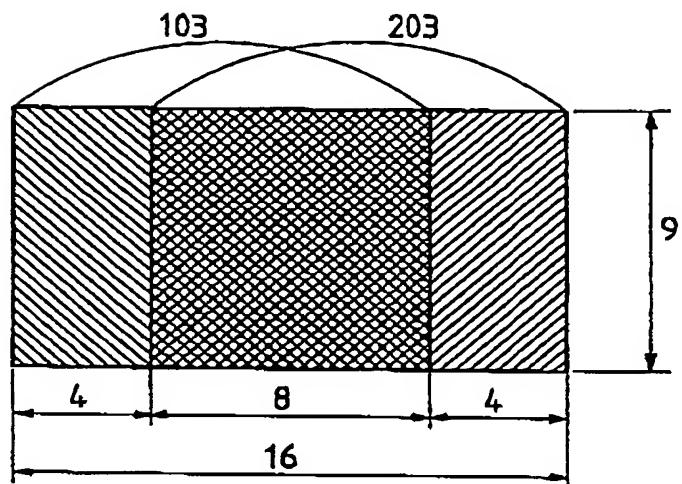
FIG. 48
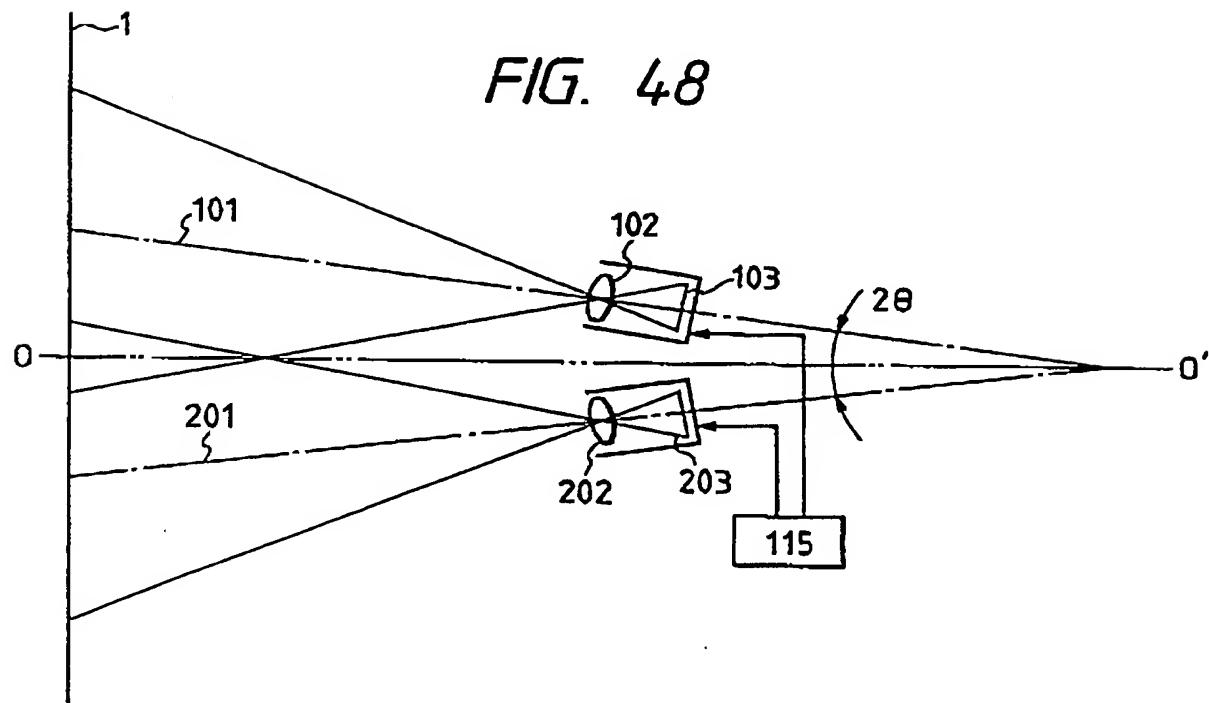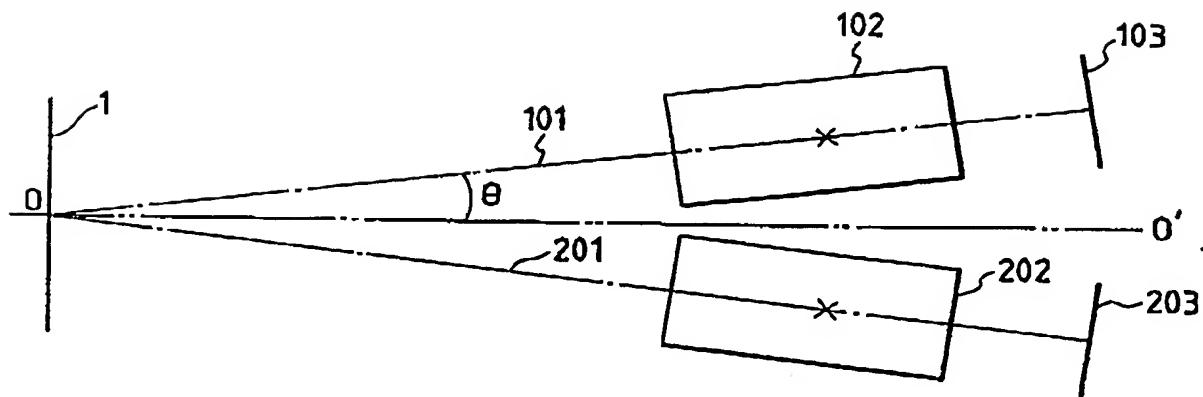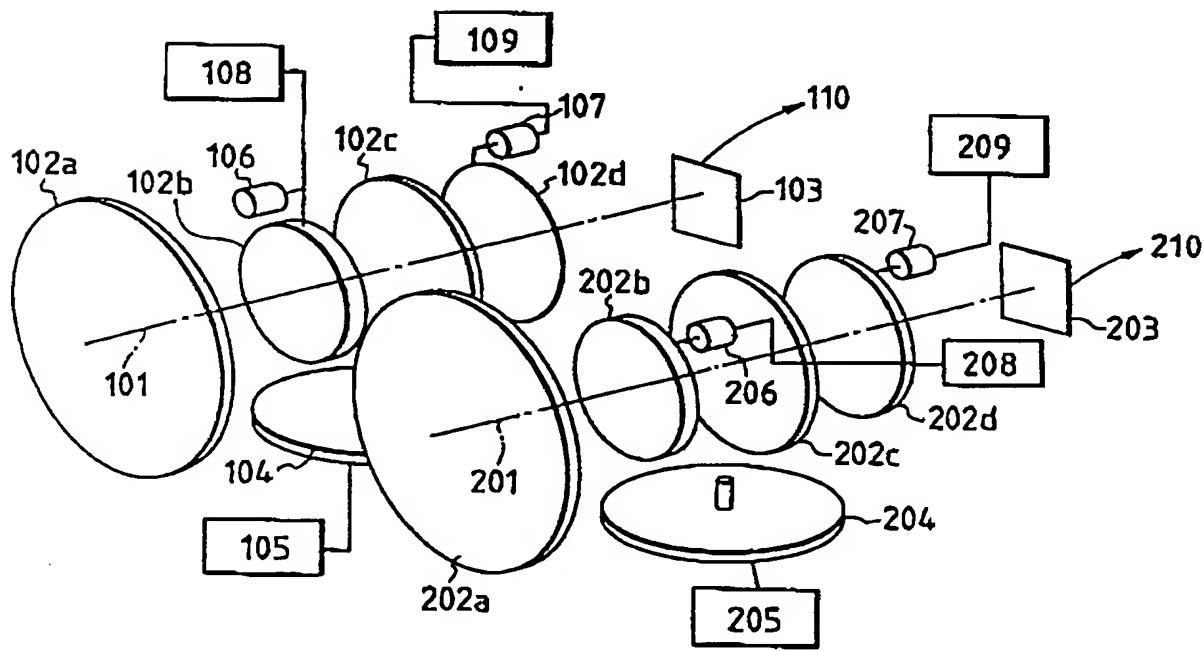
FIG. 49

FIG. 50

FIG. 51

FIG. 52

FIG. 53

FIG. 54A

$R_{ij}(X_{iR'}, Y_{jR'})$

112～

111～

FIG. 54B

112～

211～

FIG. 55

CORELATION VALUE

$X_L'(Y_L')$

PIXEL PITCH

X' (Y')
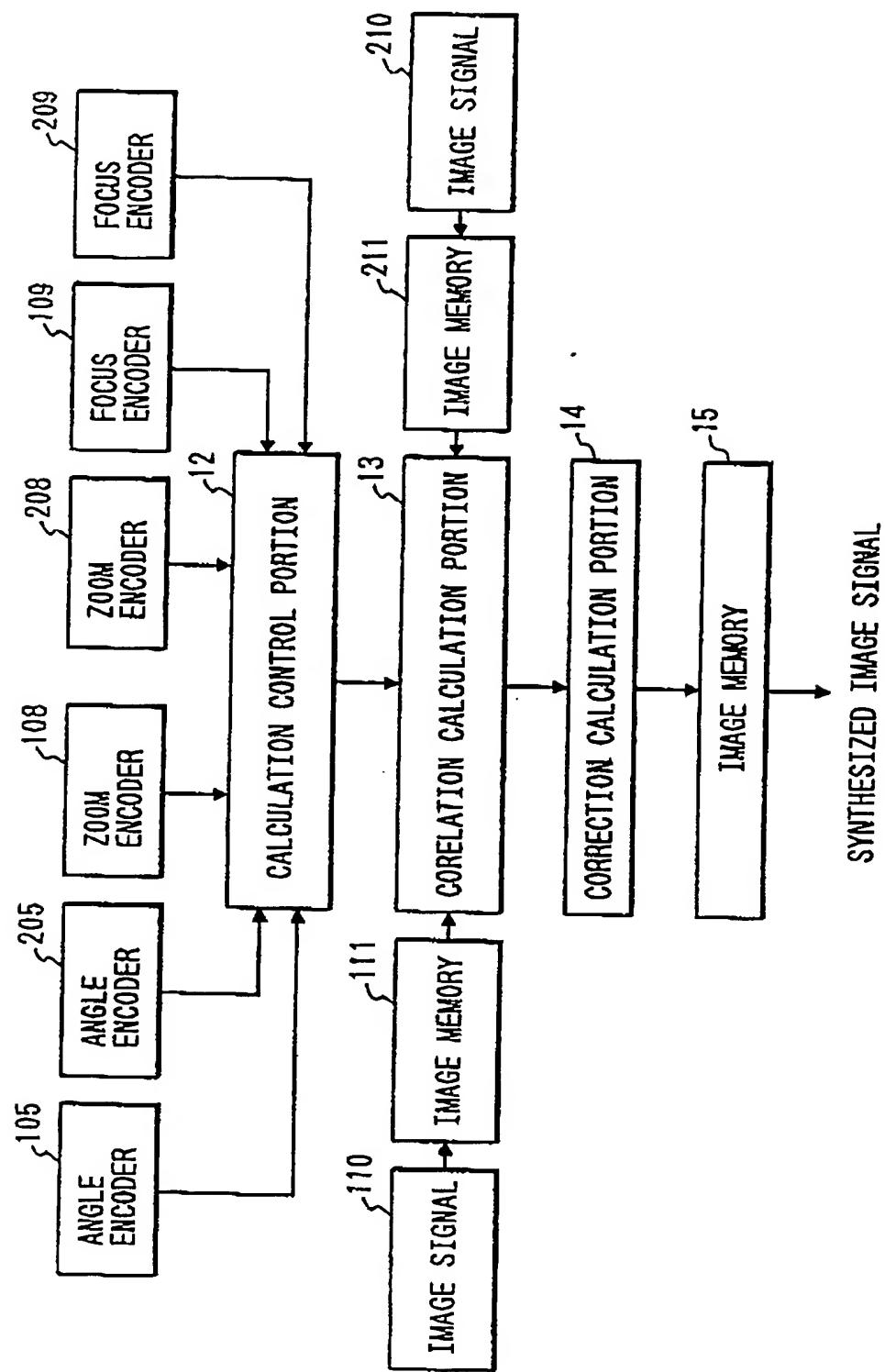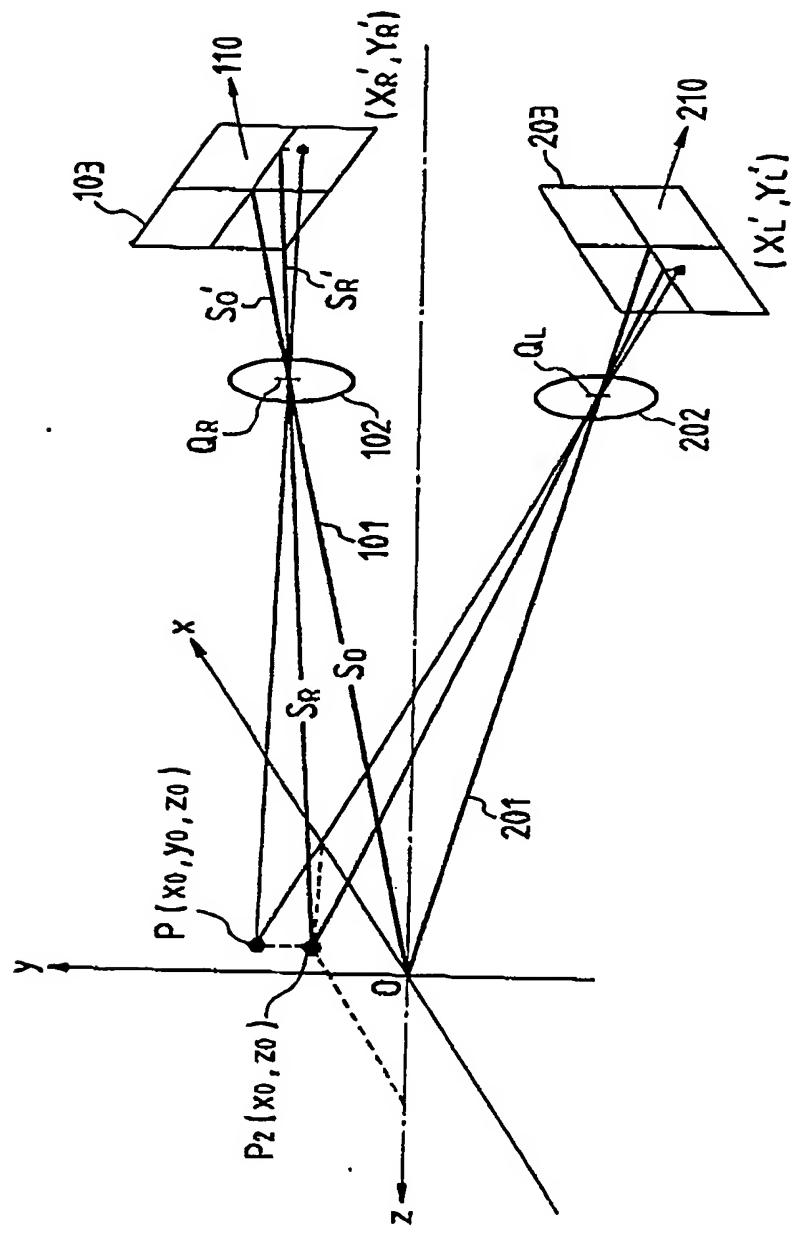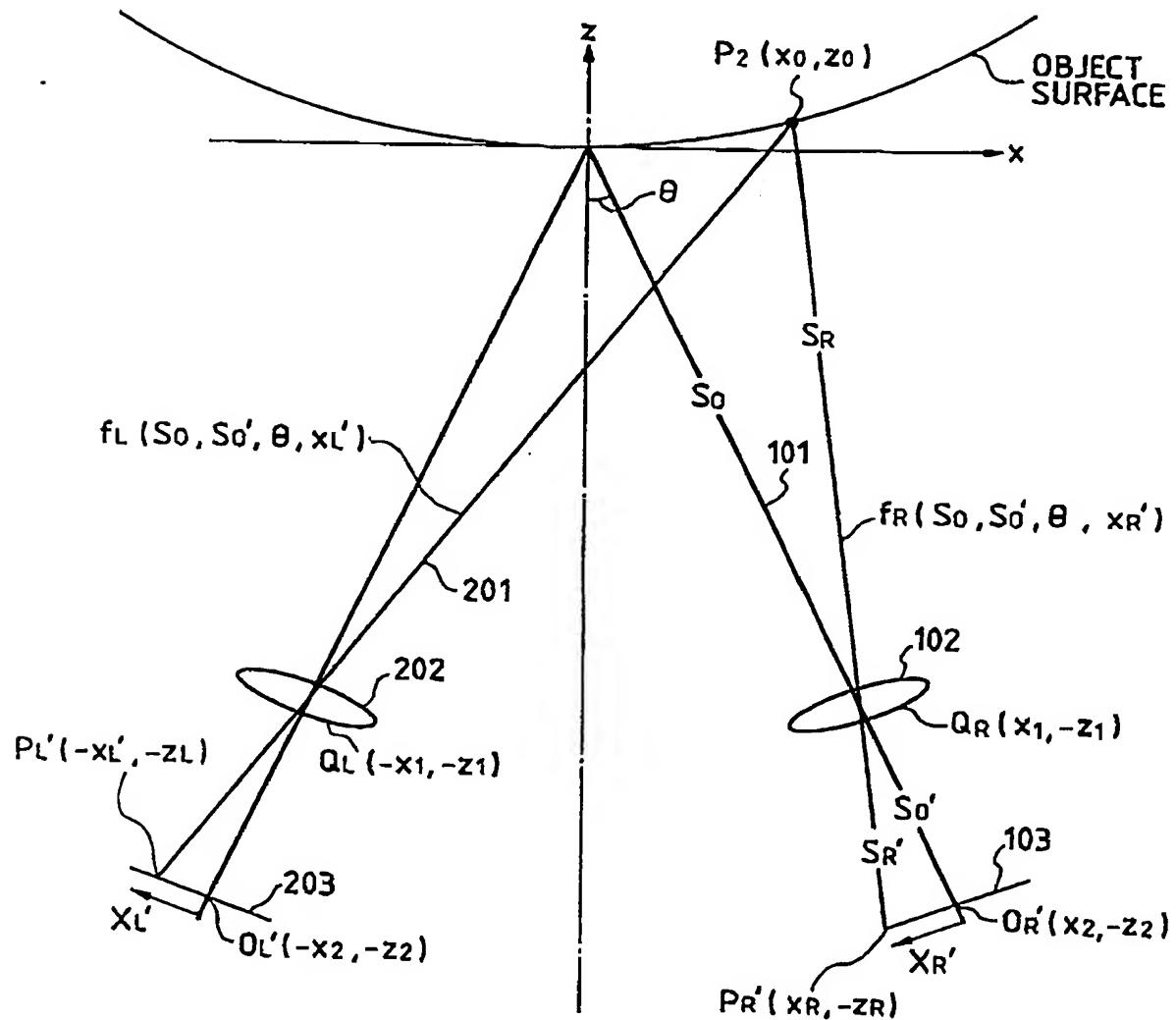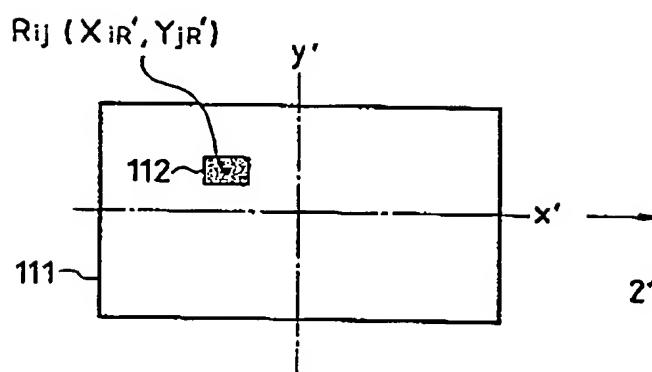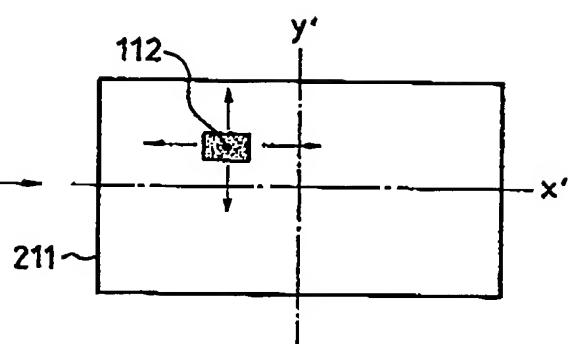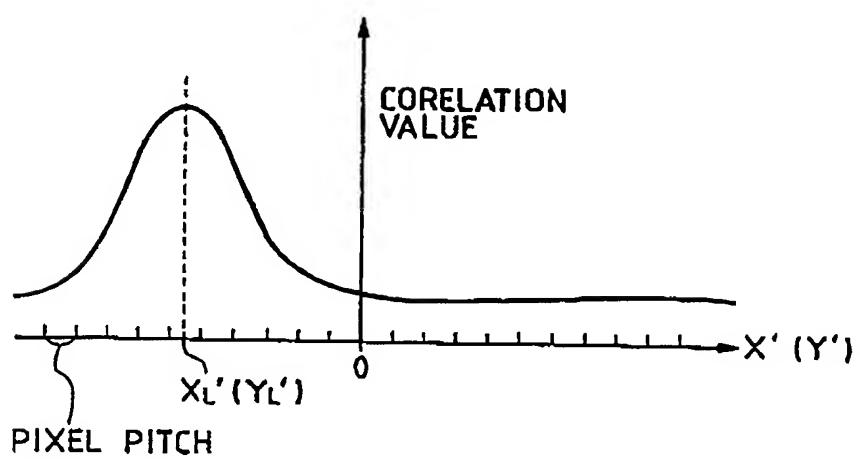
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FIG. 56

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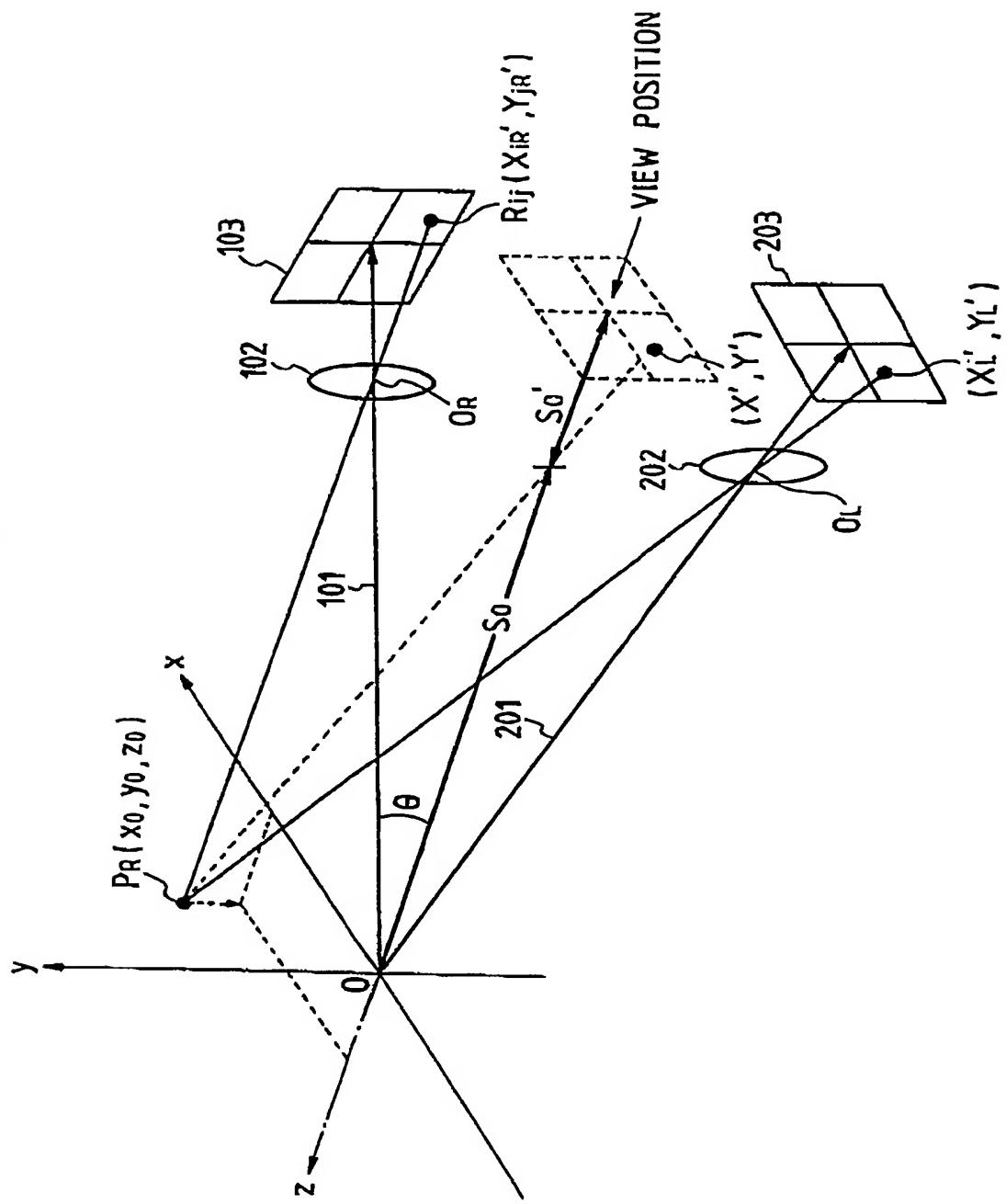
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Application Number

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	DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-2 226 923 (PENG SENG TOH ET AL.) * page 2, line 16 - page 4, line 16 * * page 5, line 10 - page 9, line 18 *	15-18	H04N13/02 H04N3/23
A		1,9, 19-23	

Y	EP-A-0 335 004 (MURAKAMI, KANJI) * the whole document *	1-6,9, 10,13, 14,22,23	
A		15-21	

Y	PATENT ABSTRACTS OF JAPAN vol. 6, no. 55 (E-101)10 April 1982 & JP-A-56 169 968 (HITASHI DENSHI LTD) 26 December 1981 * abstract *	1-6,9, 10,13, 14,22,23	

Y	US-A-4 667 236 (DRESDNER) * claim 1 *	4	
	---		TECHNICAL FIELDS SEARCHED (Int. Cl.5)
Y	EP-A-0 332 403 (SHARP K.K.) * column 6, line 12 - line 20 *	6	
	---		H04N
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 136 (E-181)(1281) 14 June 1983 & JP-A-58 051 682 (HITASHI DENSHI K.K.) 26 March 1983 * abstract *	1,3,13, 22,23	

A	PATENT ABSTRACTS OF JAPAN vol. 4, no. 32 (E-2)19 March 1980 & JP-A-55 004 192 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 12 January 1980 * abstract *	10	

A	EP-A-0 011 677 (GRUNDIG E.M.V.) * the whole document * ---	11,12	
	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06 AUGUST 1993	DE DIEULEVEULT A.J.

CATEGORY OF CITED DOCUMENTS

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& : member of the same patent family, corresponding
   document

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 248 730 (THOMSON-CSF) * column 1, line 4 - line 29 *	4,14	
A	EP-A-0 231 654 (PILKINGTON P.E. LIMITED) * page 3, line 17 - page 4, line 23 *	15-17,23	
A	SECOND INTERNATIONAL CONFERENCE ON COMPUTER VISION December 1988, TAMPA, FLORIDA, USA pages 123 - 128 TAKAHASHI ET AL. 'Self-calibration of stereo cameras'	1,9,15, 19-23	
P,A	GB-A-2 250 604 (PENG SENG TOH ET AL.) * the whole document *	6-8	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	06 AUGUST 1993	DE DIEULEVEULT A.J.